REPRODUCTION

Dozens of sperm *become stuck to the egg's jelly coat, which is made of glycoprotein, before one sperm penetrates it. The rest die and waste away.*

Gamma/Frank Spooner Pictures

MULTIPLE FISSION

ALL PLANTS AND ANIMALS need to reproduce. In this way, they make one or more copies of themselves and so make sure that others like themselves – the species – continue to survive.

The most basic living unit of virtually all living things, whether plant or animal, is a cell. To reproduce, cells must multiply. They do this by dividing themselves up.

But the word, 'division' can be misleading. New cells are not simply made up of half the ingredients of the original cell – that would make the new cells weaker and, therefore, unlikely to last long in the constant battle for survival.

Instead, when a cell first divides into two and those two into four, and so on, it remakes the ingredients of the original cell. In this way, the new cells – known as daughter cells – become very similar to the parent cells.

At the heart of every cell is a densely packed globule, *the nucleus*. The nucleus is very important in reproduction as it houses *chromosomes*, and it is the chromosomes that carry the information for making daughter cells similar to parent cells. The information that will make daughter cells similar to the parent cells is transmitted in a code by the *DNA* (deoxyribonucleic acid) within the chromosome.

SEX CELLS

Cell fission

Plants and animals can reproduce themselves in two ways. These are known as sexual and asexual reproduction.

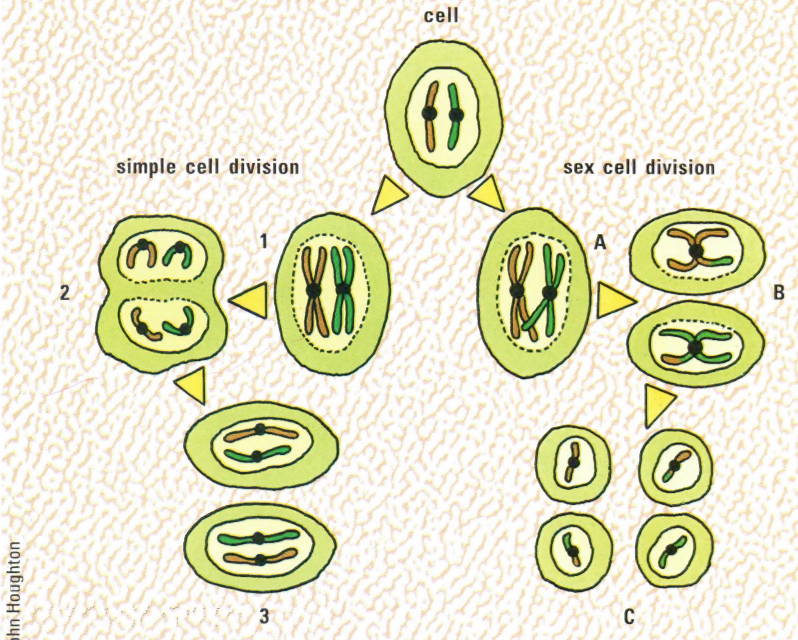
In asexual reproduction, the original cell can sub-divide and form yet another cell. This is known as *binary fission*. Extremely simple one cell plants, such as the blue green algae, do this. Bacteria too are single-celled. Under perfect condi-

INTERNAL FERTILIZATION

G I Bernard/Oxford Scientific Films

Frog spawn clusters *may contain as many as 30,000 eggs. The male clasps the female and sheds his sperm over them.*

THE THREE STAGES OF CELL DIVISION



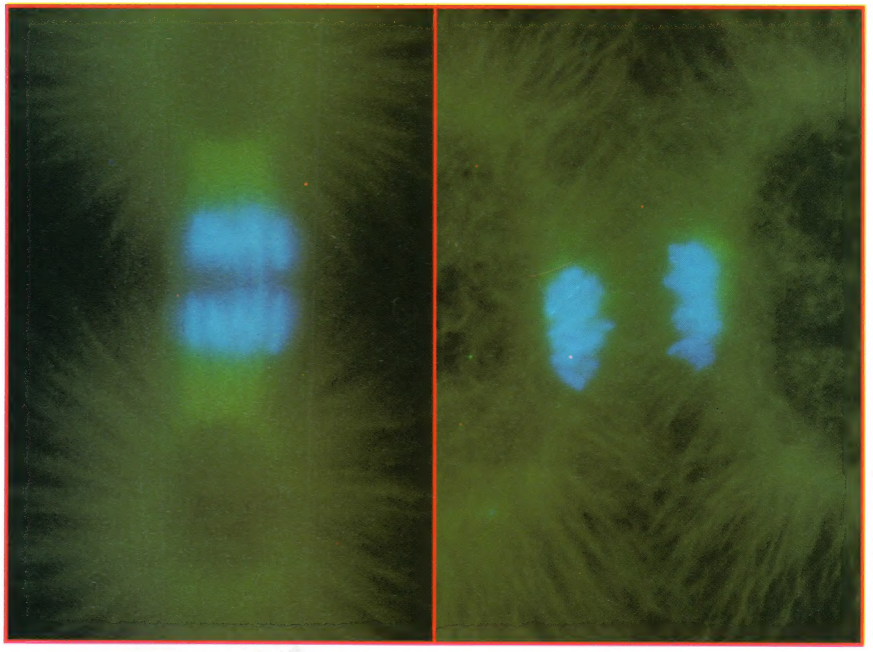
John Houghton

Simple cell division creates two identical cells from one.
1 All the chromosomes duplicate
2 The nucleus divides into two, each new nucleus containing one full set of chromosomes
3 The rest of the cell divides into two, around the nuclei

Sex cell division creates egg and sperm cells.
A Each chromosome duplicates itself and intermingles with another pair, swopping bits with each other. The intermingled pairs split apart again.
B The cell divides as in simple cell division, so that there are the same number of chromosomes in each new cell as in the original cell
C These two cells now divide *again*, without doubling the number of chromosomes beforehand. The new sperm or egg cells have half the number of chromosomes of the original.

tions, bacteria can double about every 20 minutes. This means that after 24 hours, a single cell would have given rise to more than 4,000 million million million offspring!

Another form of asexual reproduction is known as *multiple fission* because the nucleus divides repeatedly. Each new nucleus moves out of the cell, carrying with it a part of the original cell. In this way, new cells are formed, each with their own nucleus. For example, the cell bearing the disease malaria, the malarial parasite, can produce as many as 1,000 offspring when it invades the liver.



Dr Gerald Schatten/SPL

Simple cell division *takes about an hour. The chromosomes (stained blue) divide into two and then separate to the opposite ends of the cell (stained green). The cell divides to form two new cells.*

NO SEX PLEASE

Not all eggs need to be fertilized by a sperm to produce an offspring. Honey bee drones are fertile males that develop from unfertilized eggs laid by the queen. This method of reproduction is known as *parthenogenesis* (from the Greek for virgin birth).

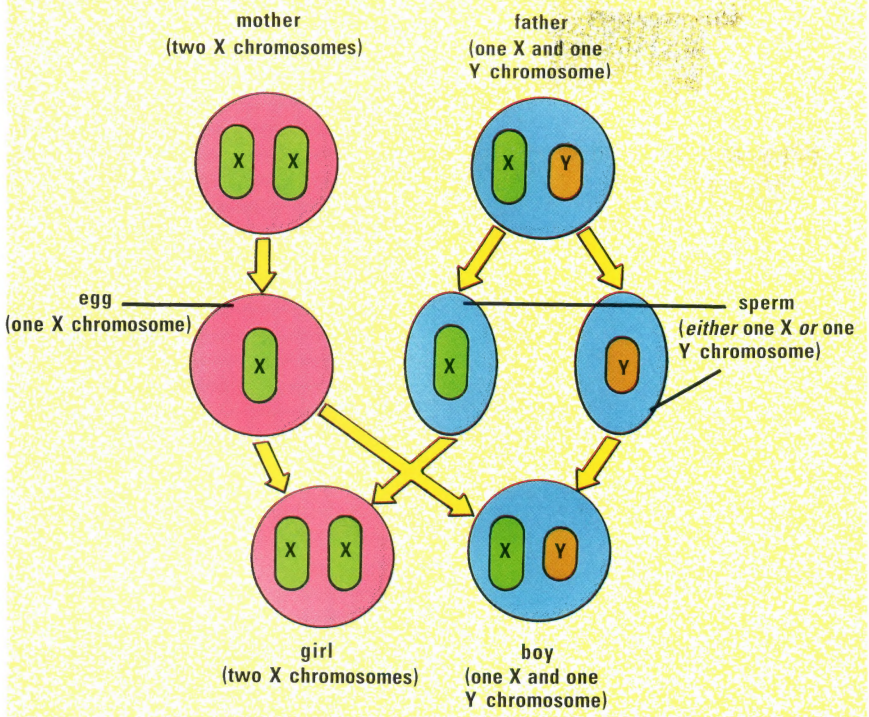
David Thompson/Oxford Scientific Films

Tiny spores

Some bacteria and other single-cell organisms, along with many plants, reproduce asexually by forming single cell bodies called spores. These leave the parent body and when they find the right conditions for germinating, sprout new offspring. Spores are usually very small and light so that they can be transported on the wind or by water and animals. Moss, ferns and many types of fungus reproduce by releasing spores.

Budding is yet another way of reproducing asexually. Yeast and many very simple animal life forms, including some worms, develop an

WHY BOYS ARE BOYS AND GIRLS ARE GIRLS



A woman has two X chromosomes in each of her cells, but a man has one X and one Y chromosome in each of his. Therefore an egg always contains one X chromosome, but a sperm may have one X or one Y.

If an egg is fertilized by a sperm carrying an X chromosome, the result is XX – a girl. But if the egg were to be fertilized by a sperm carrying a Y chromosome the result would be XY – a boy. The only sure way to guarantee the sex is to fertilize in a test tube and implant the egg.

John Houghton

outgrowth that then detaches itself and continues life on its own.

Some plants and animals literally break apart to form a new generation. This is known as fragmentation. For example, a marine worm, the nemertine *Lineus*, develops rings around its body during spring and summer. These rings tighten around the body causing bits to break off. As these bits develop into new worms, they too break up in the same way, so that one original worm could be the parent to hundreds at a time.

Often, if you take the leaf off a plant, or cut off a part of its stem, and replant it, another similar plant will grow directly from it – there is no need to plant the seeds. This process of asexual reproduction is known as vegetative propagation.

This is just how potatoes are reproduced. The part of the potato that we eat is called the tuber. The 'eyes' on the potato are buds; if the potato is planted, each eye can produce a new shoot the following year using food stored in the tuber.

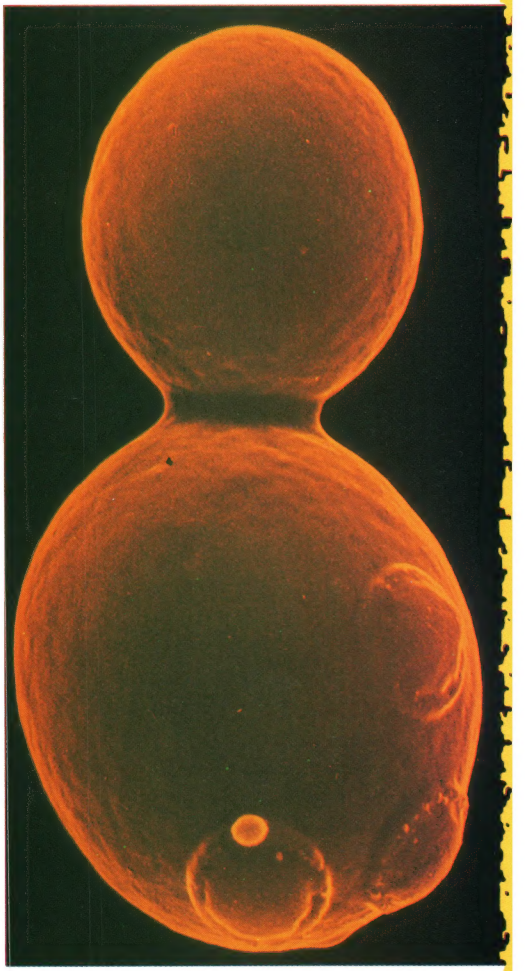
Asexual reproduction may be useful for very rapid multiplication, but it has its disadvantages: the offspring is identical to the parent. This means it cannot develop differently (evolve) to meet the challenge of changing circumstances and situations – in the weather or environment, for instance.

This problem is solved by sexual reproduction. Here, two specialized sex cells – *the gametes* – from two different sources (the male and female) come together. This means that the new plant or animal can inherit characteristics from both parents in different combinations. The number of different combinations of characteristics will keep increasing with each generation. Therefore, when circumstances change at least some of the offspring will have the right combination of characteristics to cope with the change.

For sexual reproduction to take place, the gametes must fuse properly if they are to create new life. When male and female gametes fuse, their two nuclei, each containing their own set of chromosomes, are brought together. The result, through fertilization, is a new cell and, eventually, the new many-celled plant or animal that will emerge.

G I Bernard/Oxford Scientific Films

Yellow bristles *trap pollen coated flies in the hollow base of the arum lily's spadix (central spike), together with the male and female flowers of the plant.*



J Forsdyke/Gene Cox/SPL

A yeast cell multiplies *by budding. Yeast is used to brew beer and make bread rise by converting sugars into alcohol and carbon dioxide.*

When gametes fuse

The actual process is similar in both animals and plants. When the head of the male gamete (the sperm) hits the surface of the female gamete (the egg), an enzyme which softens the surface of the egg is released and the sperm is sucked into the egg. The membrane

surrounding the egg thickens immediately and so prevents any further sperm from entering. The sperm's tail is usually discarded and the male nucleus is drawn towards the female nucleus.

In the water

The simplest way to bring together male and female gametes is to release them in water. Here they fertilize outside the parents' bodies. This is known as external fertilization. Most creatures that live in water, such as fish, and land living animals that return to water to breed, such as frogs, reproduce through external fertilization.

In most land animals, sperm from the male fertilizes the egg in the female body. This is known as internal fertilization. Internal fertilization needs a male organ, such as a penis, to penetrate the female and transmit the sperm.

In internal fertilization, the sperm have a better chance of meeting with eggs. Also, the fertilized egg is protected. It may be encased in a shell while in the mother's body and after laying, as is the case with birds. Or, as in nearly all mammals, it may be protected by the mother's uterus during its development.

A well known exception is the duck-billed platypus, a mammal found in Australia, which lays eggs and then provides milk for the offspring when they hatch.

Most plants and some animals have both male and female sexual organs. They are known as hermaphrodites. In order that they should not fertilize themselves, they have evolved some rather elaborate procedures.

A new-born kangaroo *can be only 2 mm long. Still with umbilical cord attached, the long climb to the mother's pouch begins. Once in the pouch, the young animal can suckle milk and continue growing.*

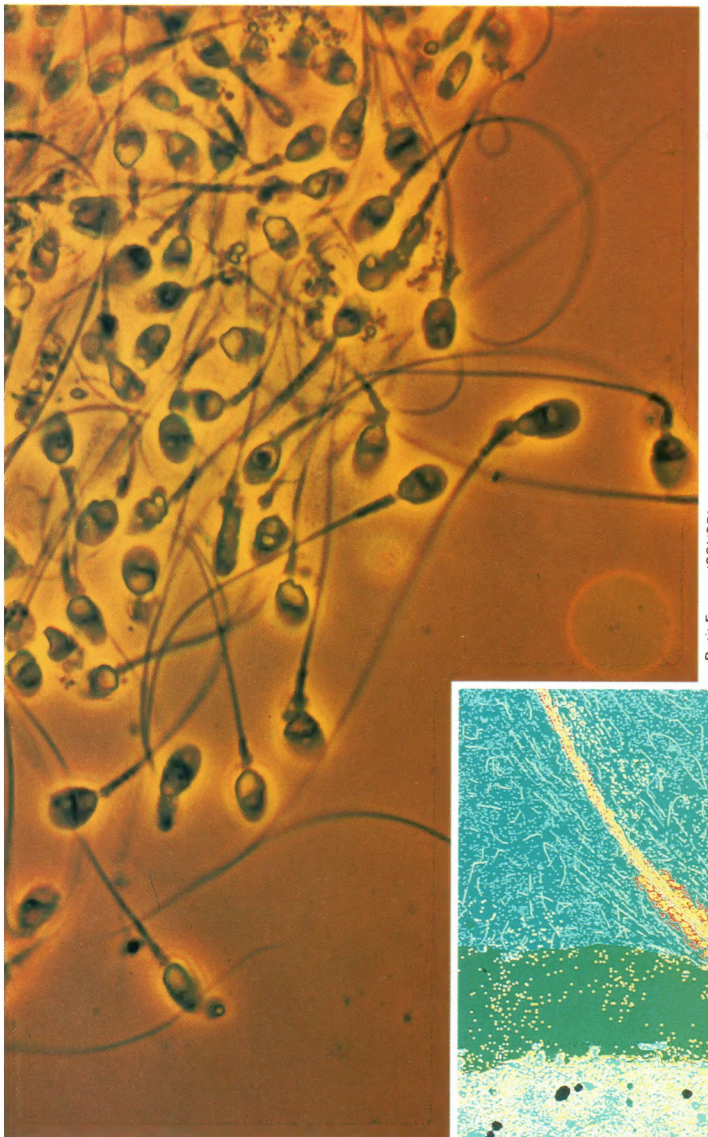
A N T/NHPA

John Walsh/SPL

Attractive aroma

The arum lily, popularly known as lords and ladies, produces a pungent smell to attract hairy moth flies. The fly, covered with pollen from other arum lilies, is trapped within the female part of the flower until pollination is complete – and they remain trapped for a further 12 hours while the male part of the flower ripens. When the flies finally crawl out, they are once again covered with pollen. The flies carry the pollen to the next arum lily to which they are attracted.

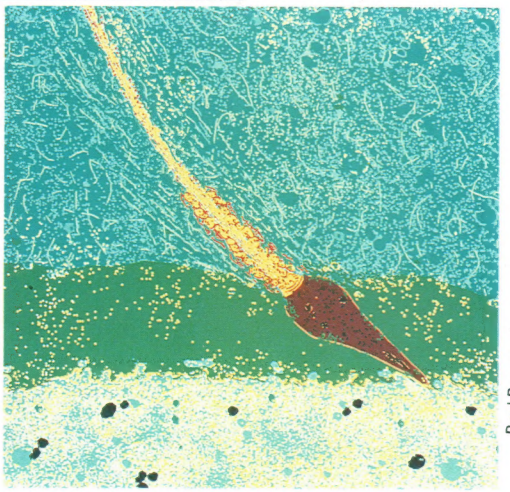
The common earthworm is hermaphrodite, having both ovaries and testes present in the same individual. So when two earthworms mate, the eggs of each one is fertilized by sperm from the other.



A large nucleus*, containing 23 chromosomes made from DNA, nearly fills the head of each human sperm. The head is attached to a tail which, lashing from side to side, pushes the sperm forward.*

A human sperm *has just penetrated the thick membrane that surrounds the egg under its jelly coat. The sperm head is about to enter the yolky substance inside the membrane.*

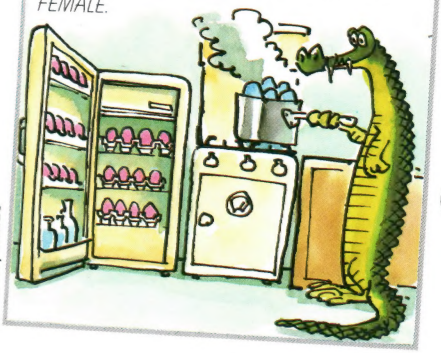
Petit Format/CSI/SPL



Just amazing!

HOT NIGHTS, COOL KIDS

THE SEX OF SOME LIZARDS, ALLIGATORS AND CROCODILES CAN BE DECIDED BY THE TEMPERATURE AT WHICH THE EGGS ARE INCUBATED. HIGH TEMPERATURES MEAN A MALE; LOW TEMPERATURES, A FEMALE.



Paul Raymonde

SEXUAL CHEMISTRY

STRANGE, AWKWARD, EVEN violent it may be, but sexual reproduction – from attraction and mating to gestation and birth – is largely under the careful control of chemicals.

Pheromones are chemical substances that are produced by one animal in order to influence the behaviour of another. They are produced by glands and excreted to the outside of the body, for example in sweat or urine. The best known pheromones act as sexual signals. The female gypsy moth produces a pheromone called gyplure which, depending on the wind, will attract a mate from up to 3 km away.

In other species pheromones may function as a repellant. Dogs are one of many animals that excrete substances in their urine, which serve as territorial markers, warning other dogs off. In this way the dog will claim all the bitches in his territory.

Invisible invitation

The existence of pheromones was proved in experiments with cockroaches. When an unmated female cockroach has crawled over a piece of paper, the paper alone is sufficient to arouse courtship behaviour in a male cockroach. The path of the female is marked invisibly with the chemical substance, which stimulates males to court her. In one particular domestic trap this courtship behaviour is turned against the cockroach by using an attractive chemical extracted from cockroach faeces as bait.

G J Cambridge/NHPA

***Pheromones** are odours used by many species to attract mates. The antennae of the male American Moon Moth can detect the smell of a female over 3 km away.*

Mouse scent

Pheromones excreted in the urine of male mice are designed to perform two distinct, but complementary, tasks. One has the effect of encouraging the female to mate; another causes abortion in pregnant females so that the new male can mate and produce his own offspring.

Hormones, like pheromones, are powerful chemical substances that influence an animal's behaviour.

Hutchison Library

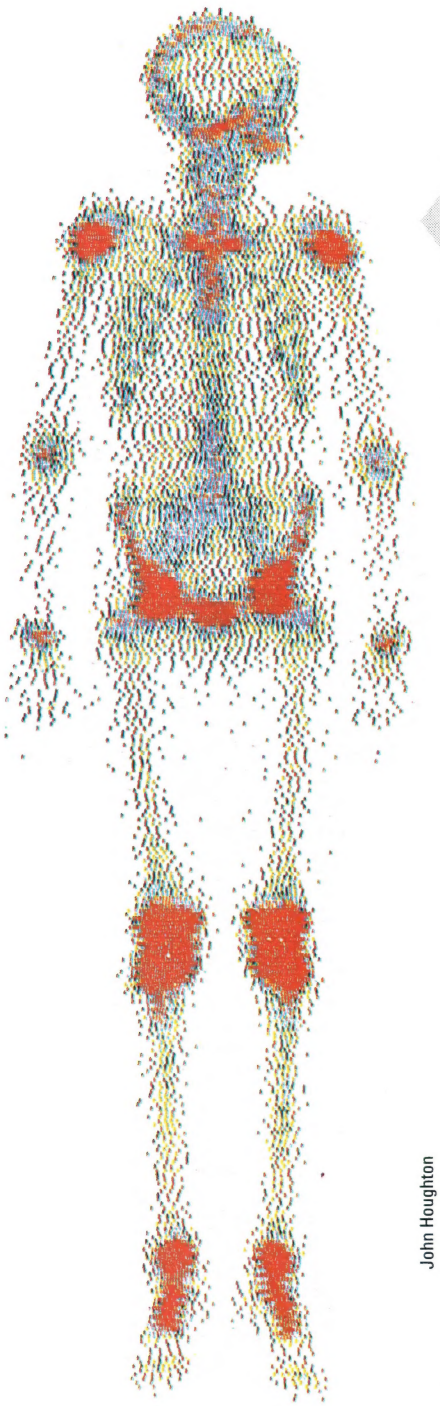
***Sexual attraction** for many animals depends largely on appearance. In humans this varies greatly between cultures in Africa and the West (right).*

Tony Stone Photo Library, London

Unlike pheromones, however, hormones are not excreted from the body but secreted into the bloodstream. Therefore, they directly influence the animal's own behaviour.

What is true for other animals is true in this case for Man. Given the right stimulus – a fleeting memory, fantasy or a real-life companion – hormones in the male and female of the species will produce, quite automatically, the whole pattern of sexual arousal that, barring intervention, culminates in the act of intercourse. It all starts in the limbic system – a network of nerve cells in the base of the brain. Its stimulation sends messenger chemicals down through the body to trigger the release of the sex hormones.

In the male this is known as



Gruppo Editoriale Fabbri

Sex hormones *stop the main bone growth throughout the body. This gamma-ray picture shows in red the normal active growth of the long bones. After puberty, when sex hormone production is increased, the red fades away as growth is halted.*

David Parker/SPL

Crystals *of testosterone, the male sex hormone – magnified 30 times. Its production at puberty stimulates the growth of the male genitals, an increase in body and facial hair, the deepening of the voice and an increase in the muscle mass.*

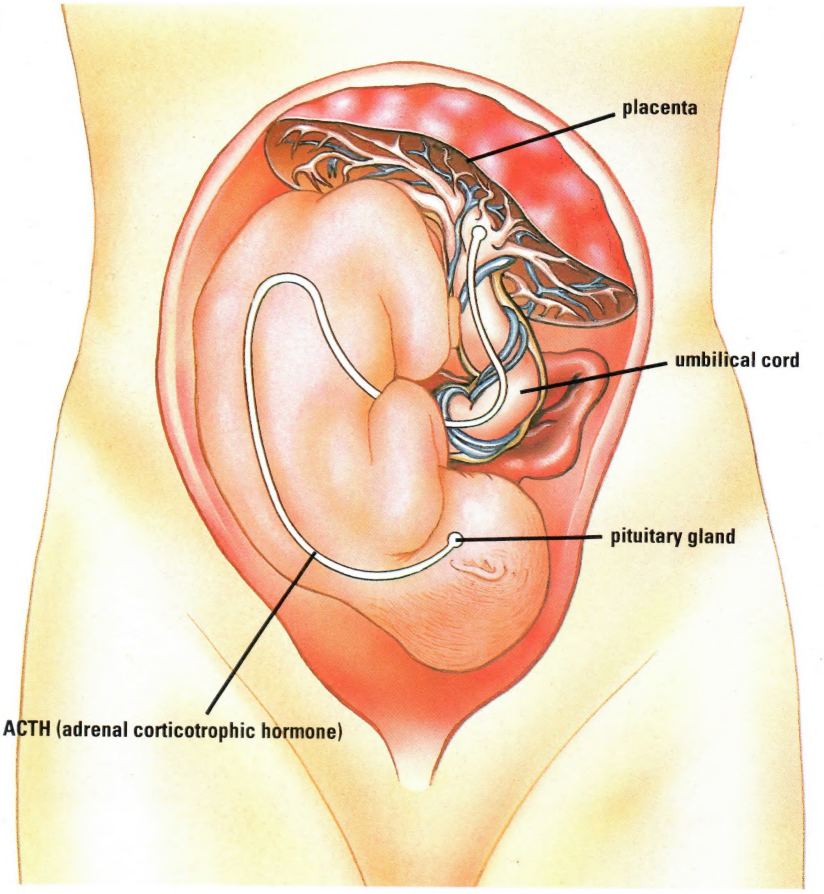
testosterone and is stored and made in the testes, the two little organs located in the human male's scrotum beneath the penis. In the female the equivalent hormone is oestrogen, the production centres for which are the ovaries – two little walnut-sized organs on the sides of the abdominal wall.

Men start producing sperm at puberty and continue up until about the age of 70. A single ejaculation contains about 300 million sperm, and in a lifetime millions upon millions are produced.

Before birth the female ovaries contain about 300,000 primary follicles (egg-producing sacs). With only one reaching maturity every month, however, only about 400 are likely to complete their development. Of these only a very small number are likely to be fertilized. At around the age of 50, women experience the menopause and stop producing eggs altogether.

Like in any complex manufacturing process, the timing of events during reproduction are crucial. Here again it is hormones that control just when, for example, the uterus (womb) wall is ready to receive the fertilized egg, the changes in the uterus during pregnancy and the onset of milk production after birth. The most obvious example of hormone controlled timing, however, is the cyclical repetition of events in the human female known as the menstrual cycle.

It all starts with the pituitary, a



John Houghton

ACTH *is the hormone, secreted by the pituitary gland of the baby, and sent via the umbilical cord to the mother, which starts the events that lead to birth.*

Just amazing!

IT'S NOW OR NEVER

ELEPHANTS HAVE THE LONGEST PERIOD OF PREGNANCY OF ANY MAMMAL LIVING ON LAND – 22 MONTHS. THEIR CALVES ARE 'PLANNED' ALWAYS TO APPEAR IN THE SPRING WHEN THE WEATHER IS MILD AND FOOD IS PLENTIFUL.

Paul Raymonde

pea-sized gland just beneath the brain, which secretes a hormone known as FSH. This goes to one of the ovaries where it causes a microscopic sac (called a Graafian follicle) to mature and migrate to the surface of the ovary. Inside the follicle is an immature egg. The FSH also stimulates the ovary to keep secreting another hormone called oestrogen. After 14 days, the build-up of the oestrogen stimulates the pituitary to release another hormone called LH. LH induces the Graafian follicle to release the now mature egg. This is known as ovulation. After ovulation the Graafian follicle secretes yet another hormone called progesterone.

Progesterone prepares the uterine wall for implantation in case fertilization occurs and inhibits the production of FSH so that no more follicles develop. After a further 14 days the level of progesterone rises to a point at which the lining of the uterus, together with the unfertilized egg is expelled from the uterus in a process known as menstruation. It is at this point that the oestrogen comes into its own, helping to repair the wall of the uterus. For most women the whole cycle takes 28 days but stress, shock or illness can upset the hormonal balance and cause this to vary.

Conception

Menstruation only occurs if the egg is not fertilized. But if the egg is fertilized, it usually becomes implanted in the wall of the uterus and pregnancy results. When this happens, the Graafian follicle continues to produce progesterone. This, together with a steady flow of oestrogen from the ovaries, prepares the uterus for pregnancy, preventing menstruation.

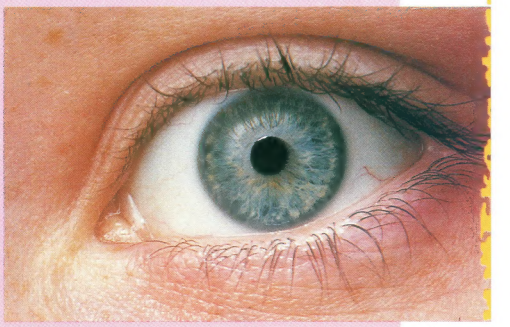
The progesterone also prevents further follicles from developing so that ovulation does not occur during pregnancy. As the placenta (the organ in the uterus that helps to nourish the foetus) grows, it takes over the role of producing progesterone and the Graafian follicle breaks down and wastes away.

Towards the end of the pregnancy (40 weeks or 9 months for humans) the level of progesterone decreases and that of oestrogen increases. It is these changes that help to bring about the birth. Labour and its climax are the most dramatic examples of the controlling power of hormones.

However 'ready' a mother-to-be believes she is, it is the baby that actually sets the chain in motion. When it is ready – and many doctors believe that psychological factors may be important – the baby releases a hormone called ACTH (adrenal corticotrophic hormone). ACTH stimulates the mother's tissues to synthesize a hormone called prostoglandin, a chemical that makes the uterus start contracting, heralding the onset of labour.

Then, as soon as he or she is born, the baby may go to the breast where a cocktail of antibodies, designed to fight infection, waits for the first, comforting, sucks of life.

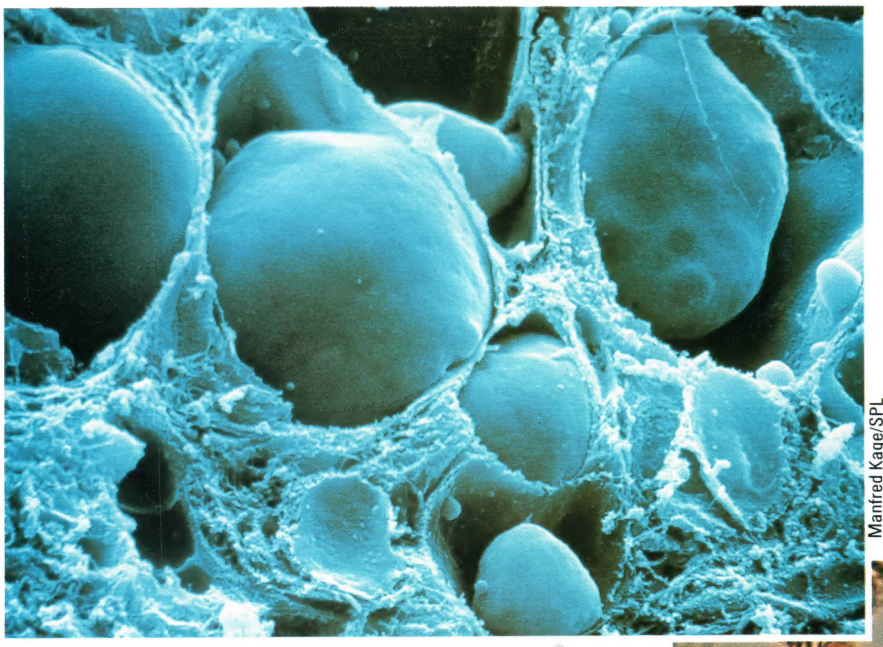
EYE SIGNALS



Martin Dohrn/SPL

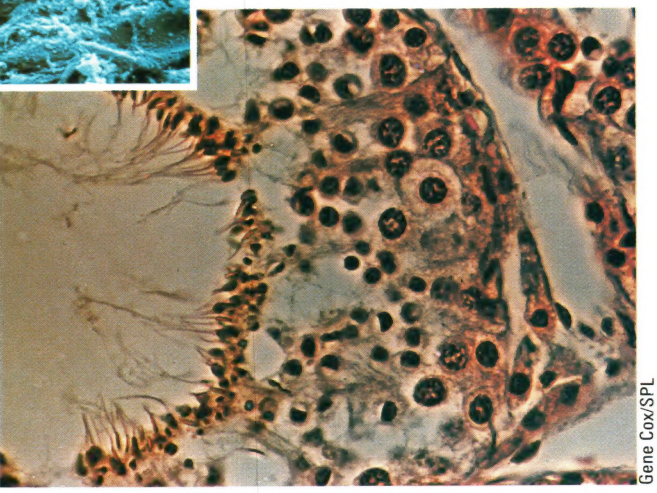
The first sign of sexual attraction are the eyes. As blood pressure rises, the pupils begin to open. In less than a fifth of a second they dilate, pulled by tiny muscles in the iris, from 2 mm in diameter to 8 or 9 mm.

At the same time, the eye itself moves rapidly after the subject of arousal, pulled by the six muscles in the eye socket. The blinking of the eyelid increases dramatically and the eyes are sprayed with a fine mist of tears, giving rise to the dewy-eyed gaze so often attributed to eager lovers. Women often emphasize their eyes with make-up to imitate this effect.



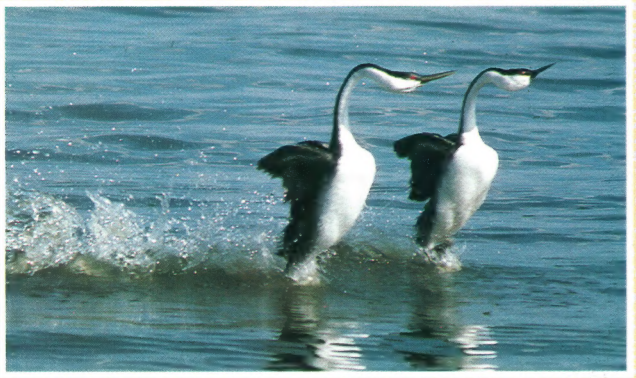
Manfred Kage/SPL

A woman is born *with half a million egg cells. Of these, only one per month develops to maturity in the ovary wall.*



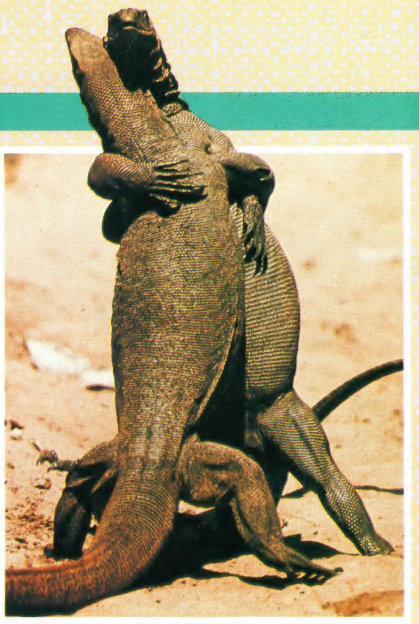
Gene Cox/SPL

Sperm, *in their millions, being produced in tiny tubes within a male's testes in a process known as spermatogenesis.*



Charlie Ott/Bruce Coleman Ltd

The mating run *of the Western Grebe, a native duck of California. Such behaviour is performed to stimulate the hen to become sexually receptive.*



E Zingel/Frank Lane Picture Agency

Two male *Bengal Monitor lizards engage in the species' fighting dance to establish dominance.*

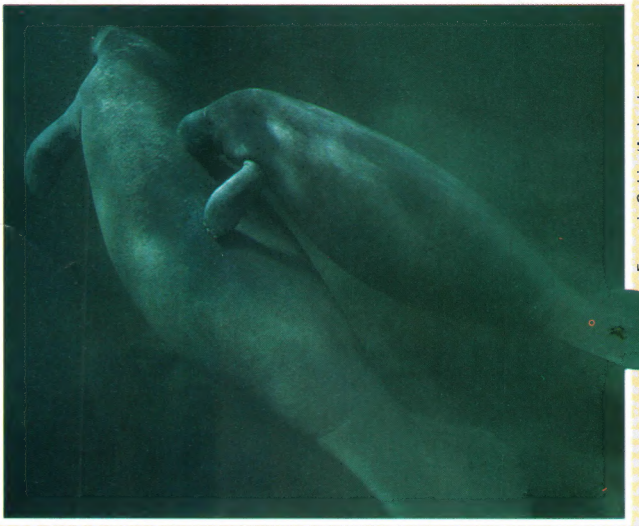
The Sea Cow*, or Manatee, of the Atlantic tropical and subtropical coasts, engages in courting play.*

The jaws *of the Stag Beetle resemble antlers. Their only use is as a weapon against other males in their fight for first choice of mates.*

Stephen Dalton/NHPA

Bugling *is the term used to describe the ritual roar that a Red Deer stag performs. The loudness and frequency of the roar is linked to fighting success.*

Manfred Danegger/NHPA



Francois Gohier/Ardea London

Clem Haagner/Ardea London

The Great Bower *Bird of Australia and New Guinea is known for the ground nests or bowers, built by the male over several months, in order to attract a mate.*

H & J Beste/Ardea London

Giraffes *begin their courtship when the bull rubs necks with the cow in an action known as necking. A cow will mate with the dominant male in the area.*

Tom Ulrich/Oxford Scientific Films

Many animals fight *to establish a hierarchy among the males prior to mating. Bighorn sheep of the Rocky Mountains, USA, head butt to determine dominance. The highest ranking males have priority to the females as they come into heat.*

BIOLOGICAL CLOCKS

- CAMOUFLAGE
- TELLING THE TIME
- THE HYPOTHALMUS

EATING, SLEEPING, HEADING south for the winter – these and many other vitally important, recurring activities in the natural world are timed by 'biological clocks' with remarkable precision.

Animals and plants have a natural sense of when to perform many regular and necessary actions. The effect of their internal time sense can be observed, but how biological clocks work, or where they are located, cannot yet be fully explained.

External influences such as heat and cold, light and darkness, ensure that an animal's or plant's biological clock is set to the right time – that a particular activity continues to happen at a certain time of day. But in a laboratory, away from these outside stimuli, similar cycles of behaviour continue.

***The lunar day**, from moon rise to moon rise, is 24.8 hours long. The moon pulls the sea towards it, causing two high tides a lunar day. Many plants and animals in the sea and on the shoreline time their activities by the rhythms of the moon and tides.*

In their natural surroundings, earth worms, for example, need to stay below ground during the day to avoid the danger of drying out. They come up at night when the air is moist and cool. While they are below ground they cannot 'tell the time' by means of daylight or temperature. They need their internal – biological – clocks to tell them when to come up.

These biological clocks keep working even in a laboratory, where there is no day or night. Earthworms kept in glass jars of soil in a darkened room rise to the surface and become active once every 24 hours, then burrow down again to rest. Their cycle of activity keeps time with the unseen day and night outside in the open air.

Biological clocks most commonly have a 24-hour cycle. In a laboratory, rhythms of behaviour frequently continue over periods of time slightly longer or shorter than 24 hours. For this reason they are called 'circadian' – 'about a day'.

Plants also have circadian rhythms. The leaves of plants lift and droop, under the guidance of their internal clocks, to maximize the light they receive from the sun. The leaves of a bean plant kept in darkness also lift when the day outside begins and droop when it ends.

Circadian clocks

Flowers open so that they are ready at the time of day when it is most likely they will be visited by insects. They synchronize their opening with other plants of the same species, so that the insects can cross-pollinate them.

A plant's circadian rhythm can be altered by changes in temperature. The tropical African violet, for instance, grows best at a temperature of 20°C. At 10°C its cycle slows to 32 hours. In the wild it would die with a rhythm that was so badly mismatched with the length of the day. But kept in a laboratory with a regulated 32-hour cycle of darkness and light, the plant flourishes at the lower temperature.

Many sea creatures have patterns of activity linked to the rhythms of the tides. Generally there are two high tides a day, separated by roughly 12½ hours.

The fiddler crab knows when to emerge from its burrow in the sand near the water's edge – twice a day, at low tide. It scurries about, feeding, courting or mating, then buries itself before the tide comes in again. Kept in darkness in a laboratory at constant temperature, with no tides, it follows the same pattern of activity for weeks.

Internal clocks controlling annual changes are called 'circannual' – 'about a year'. Animals and plants adapt to a new season – the adaptations are started by changes in the temperature and the number of daylight hours.

Stags shed their antlers in the early spring and then start to grow new ones. The arctic hare, the arctic

Some cacti flower *as soon as daylight disappears and night falls. The flowers die before dawn. The Night Flowering Cactus, also known as Queen of the Night, comes from Mexico.*

A polar bear's *coat serves as camouflage. The fur will change from white to brown in the spring, when higher temperatures and longer daylight hours have melted the Arctic snow.*

Peter Johnson/NHPA

ZEFA

The map butterfly *Araschnia levana changes from a caterpillar to a pupa in the autumn prompted by the shortening day.*

E J & J S Woolmer/Oxford Scientific Films

The same butterfly *produces different markings when it changes into a pupa in the spring.*

fox and the polar bear change their camouflage – turning white as the winter approaches and days shorten. Their coats darken with the coming of spring.

But when certain animals have been kept away from natural signals, such as changes in light and temperature, for periods of several years, they have continued these rhythms. Ground squirrels from the Rocky Mountains were kept indoors for three years. The temperature was maintained at just above freezing point and the length of their artificial days was always the same, so the squirrels did not receive the usual signals that winter was about to begin. Yet each October they began to hibernate as usual.

Out of sync

The squirrels' clocks, however, did run a little fast. Each year they hibernated slightly earlier than they would have in the wild. In laboratory conditions biological clocks always run a little fast or slow. Outside, daylight and temperature changes trigger alterations in behaviour and by doing so keep resetting the internal biological clocks so that they remain accurate.

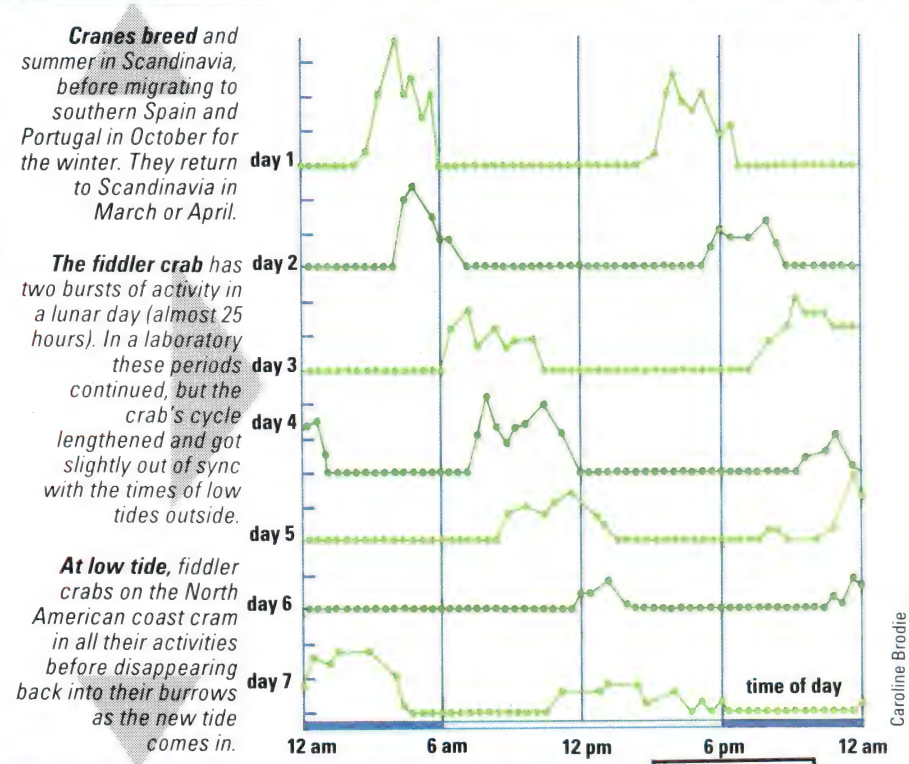
The shortening day, as winter approaches, prompts many species

Frank Lane Picture Agency

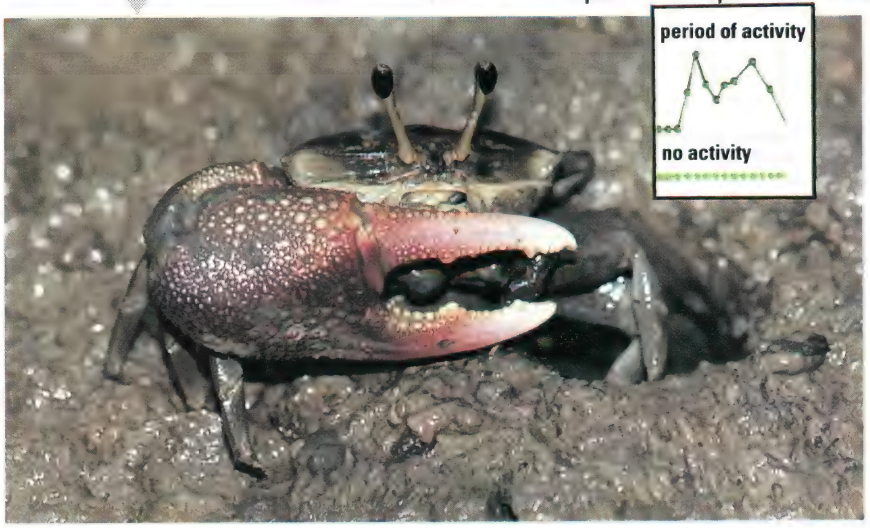
Cranes breed *and summer in Scandinavia, before migrating to southern Spain and Portugal in October for the winter. They return to Scandinavia in March or April.*

The fiddler crab *has two bursts of activity in a lunar day (almost 25 hours). In a laboratory these periods continued, but the crab's cycle lengthened and got slightly out of sync with the times of low tides outside.*

At low tide, *fiddler crabs on the North American coast cram in all their activities before disappearing back into their burrows as the new tide comes in.*

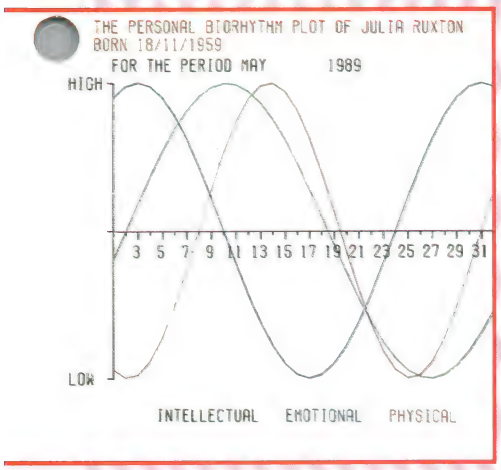


Caroline Brodie



Keith Scholey/Planet Earth Pictures

BIORHYTHMS

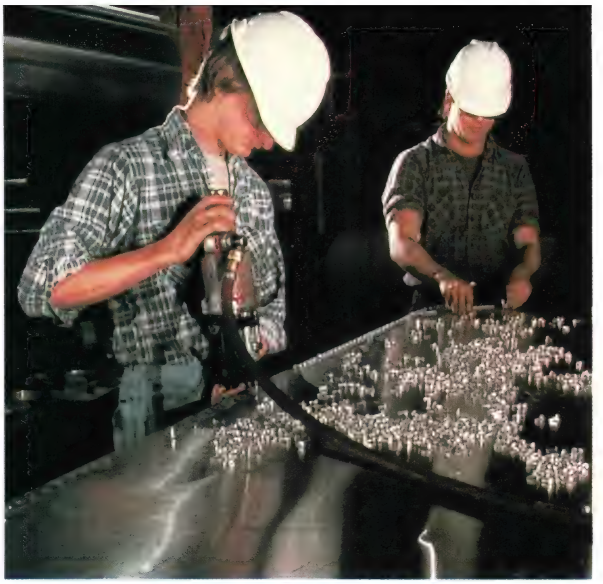


London Biorhythm Company

Many people say our moods, our thoughts and our state of health fluctuate in three different cycles, called 'biorhythms'. Biorhythms tick away at an unvarying rate from the moment of birth. We have an emotional 'high' every 28 days, while our body state varies in a 23-day cycle, and our mental condition in a 33-day one. When a cycle crosses the midline from high to low, or vice versa, that is a 'caution' or 'critical' day. On a caution day we may have an accident, be moody or make a bad decision. Scientific studies do not support the idea of biorhythms. If biorhythms do exist, they are the most amazingly precise biological clocks of all. In Japan they are taken very seriously – airline pilots are advised not to fly on their caution days.

of birds to migrate to the tropics. Just when warblers living in the wild are beginning their annual migration to the south, caged garden warblers become restless, too. A caged warbler lives in a room with artificial day and night, and yet it has an inbuilt urge to be off at this time of year.

The biological clock of a mammal, including a human being, seems to consist of a group of no more than a few thousand cells in a gland called the hypothalamus, just under the brain. These cells fire off electrical signals at a regular rate. (Such cells in rats' brains keep on 'ticking' even when removed and kept alive outside the animal.) The hypothalamus lies just above the point where the optic nerves from the eyes join – well placed to absorb information from the day and night cycle, which will keep the internal clock accurately set.



Tony Stone Photo Library, London

Car workers *on the night shift are not as efficient as they would be during the day – their internal body clocks will not fully adapt.*

Spectrum Colour Library

Leaves grow and fall *from a beech tree, photographed in June, October and December. Changes are triggered by alterations in day length, temperature and light intensity.*

There are 'rhythms' – regularly occurring sequences of events – in the human body. The chemical composition of the blood and the urine changes throughout the 24 hours of the day. When scientists at Spitsbergen, inside the Arctic circle, carried out their daily routines first by 21 hour 'days' and then by 27 hour cycles, the chemistry of their bodies stubbornly kept to a 24-hour circadian rhythm.

The menstrual cycle of women is a very important monthly cycle. Each month an egg is prepared for possible fertilization and the lining of the uterus is shed. The average length of the cycle is one lunar month (28 days), although it tends to vary slightly between one woman and another.

JET LAG

Leaving New York at 6 pm, you arrive in London at 6.30 am after a flight of seven and a half hours. London is five hours ahead of New York. Everyone in London is alert, ready to begin a new day. But the thought of activity of any kind fills you with horror – you feel tired, even ill. This is the condition known as jet lag. Your 24-hour body clock, which dictates the times for waking up, feeling hungry, going to sleep and so much else, is still set to New York time. A flight from New York needs a day's rest for recovery – double the distance, and you may need two and a half days to get your body clock 'in sync' with your new surroundings. There is no medicine for jet lag, except proper rest at the end of the flight.

Sense of timing

Our perception of how quickly time passes changes. To a child the day often seems longer than to an adult. One reason is that the heart of a human baby beats 140 times a minute, but an adult's heart beat has slowed to 70 a minute. The faster the heartbeat, the faster the pace of life, the more is crammed into the day and the longer the day seems to have been when you look back at it later.

Man is not very good at guessing how much time has passed. In an experiment, volunteers were kept isolated, in darkness and silence, for days at a time. Some were asked to press a button whenever they guessed that an hour had passed. You might expect that, being bored by the monotony, they would press the button much too often and overestimate the time they stayed in the 'black room'. They never did. Some of the volunteers made quite accurate estimates, but an equal number underestimated the passing of time wildly – one person thought he had been confined for 57 hours instead of 96.

Paul Raymonde

AGEING

Gamma/Frank Spooner Pictures

The human life, *from infancy to old age, is marked by a progressive degeneration known as ageing.*

CNRI/Science Photo Library

THE MAXIMUM HUMAN lifespan has not increased significantly since the Stone Age. Although average lifespans have increased dramatically in the last few hundred years, the maximum life expectancy remains at around 100 years.

Since the dawn of time Man has agonized over the meaning of life and death, but it is a biological fact that the evolution of species depends on the death of individual creatures. If a new generation, incorporating improvement, is to flourish, the previous generation must get out of the way. In other words, a species benefits if its members are 'programmed' to die.

Memory *and thinking speed diminish with advancing age due to the withering of the dendrites, the long, limb-like links between nerve cells of the brain, and the death of the nerve cells themselves.*

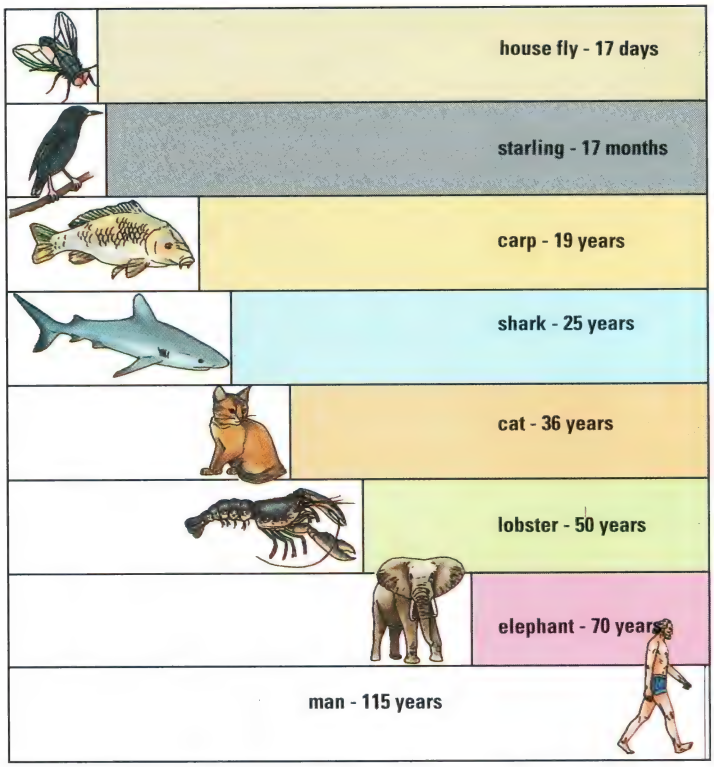
Many plants, for example, die immediately after they have scattered their seeds. Similarly, animals that reproduce only once in their lives, for example most insects, generally die immediately afterwards. Animals that breed repeatedly during their lives, larger mammals for instance, do not have such a sharply defined time of death, but they do deteriorate as they age.

Tony Stone Photo Library, London

Deep roots

The oldest living thing alive on Earth today is an evergreen shrub called the box huckleberry, growing in Pennsylvania, USA. This single plant straggles along a slope by the River Juniata for more than 1½ km. It is reputed to be at least 13,000 years old.

Much younger is a bristlecone pine tree, growing high on a mountain in Nevada, at 4,600 years old. And some of the giant sequoia trees of California are estimated to be between 3,500 and 4,000 years old.



Caroline Brodie

***Humans** have a long life compared to most other animals. In general, the bigger an animal the longer it lives, but there are exceptions – the tarantula can reach 28 years and some deep sea clams have a recorded lifespan of 100 years.*

***Fransie Geringer**, a 7-year-old who suffers from progeria, a rare disease which causes children to have the appearance of premature ageing. Sufferers rarely live beyond the age of 15–18, normally dying from heart failure.*

Nothing in the animal kingdom can match these lifespans. Giant tortoises have commonly lived up to 150 years. Lake sturgeon (a primitive fish) have probably lived to 100 years.

Human beings are long-lived by comparison with most animals. The longest definitely established human life was 120 years 237 days, achieved by a Japanese man named Shigechiyo Izumi.

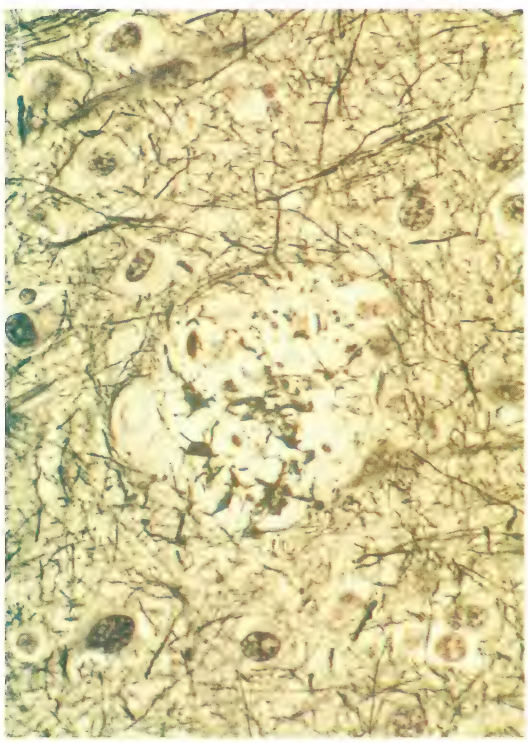
It is wrong to think of ageing as an illness. Ageing is a process that goes on over the entire passage of an adult lifespan and is as much a part of living as infancy, childhood and adolescence. The effects which are popularly associated with ageing, such as physical weakness or loss of mental ability, are in fact the effects of disease and not ageing itself.

Ageing theories

As people age, a number of changes occur within the body. These changes become visible both in appearance and behaviour. The ageing process starts on a cellular level and it is to the cells that scientists investigating ageing first turn their attention.

Cells are like chemical factories, manufacturing substances essential for themselves and the body. One theory of ageing, the mutation theory, is that chance errors build up over time. If the cell is one of those that reproduces itself, these errors will be passed on to the new cells and some errors will arise in the copying process. These errors build up until the cells cannot work properly.

According to another theory, the wear-and-tear theory, the waste products of body processes build up until cells can no longer work properly. Yet another theory, the auto-immunity control theory, holds that in old age the body's defence system (which attacks bacteria, viruses and poisons) goes wrong and starts to attack the body's own cells.



Science Photo Library

***Alzheimer's disease**, or senile dementia, results from the destruction of brain cells in old age as plaques – the pale area – are formed in the brain tissue. It causes forgetfulness and the inability to reason clearly.*

Although on a cellular level ageing begins very early in life – for the brain, at least, at 7 years of age – most of its effects do not start to make themselves felt until much later in life. Of greatest significance are the following:

- The muscles of *the heart* deteriorate. Between the ages of 20 and 90 the amount of blood pumped by the heart decreases by 50 per cent. (Although the walls of the larger blood vessels thicken, so making the heart work harder, hardening of the arteries, called arteriosclerosis, is a disorder which can appear even in adolescents)
- Although the loss of teeth is

Gamma/Frank Spooner Pictures

Just amazing!

DYING FOR A SMOKE

EACH CIGARETTE SHORTENS A SMOKER'S LIFE BY 5½ MINUTES ACCORDING TO AN ESTIMATE BY THE ROYAL COLLEGE OF PHYSICIANS IN LONDON, UK.

Paul Raymonde

Gamma/Frank Spooner Pictures

***Hulda Crooks** of California, USA was 91 in 1987 when she became the oldest woman to climb Japan's Mount Fuji. Since turning 65, she has climbed over 97 peaks above 1,600 metres.*

more the result of long-term neglect than ageing, the overall process of *digestion* is not significantly impaired in the elderly

- From the middle 20s to the 50s there is a slight decline in *visual acuity* (the ability to see fine detail). Distant objects can ordinarily be seen more clearly than close ones with increasing age. Old age also sees a greater incidence of eye diseases such as glaucoma and cataracts
- *Hearing* changes little with age but over 50 there is a gradual reduction in the ability to hear high frequency tones
- After 70 there may be a reduction in *taste sensitivity* associated with loss of taste buds from the tongue. The *sense of smell* seems little affected
- *Reflexes* become increasingly sluggish after 70
- The *skin* loses elasticity and wrinkles develop
- The *bones* lose calcium with ageing, becoming more fragile and therefore more likely to break. Healing is slower, the mobility of joints diminishes and the incidence of arthritis increases
- The efficiency of *the respiratory system* gradually diminishes as the bony cage of the chest stiffens, muscles lose their strength and the lungs themselves become less elastic
- *Physical capacity* is reduced in the elderly because of the inability to deliver enough oxygen to the working muscles
- *Short-term memory* worsens and response time lengthens with age.

The study of ageing is called gerentology and doctors specializing in this field have discovered that the biological make-up of a fit 60 year old is hardly different from that of a fit 30 year old. Correct diet, moderate exercise and not smoking will help to avoid diseases of the heart and lungs.

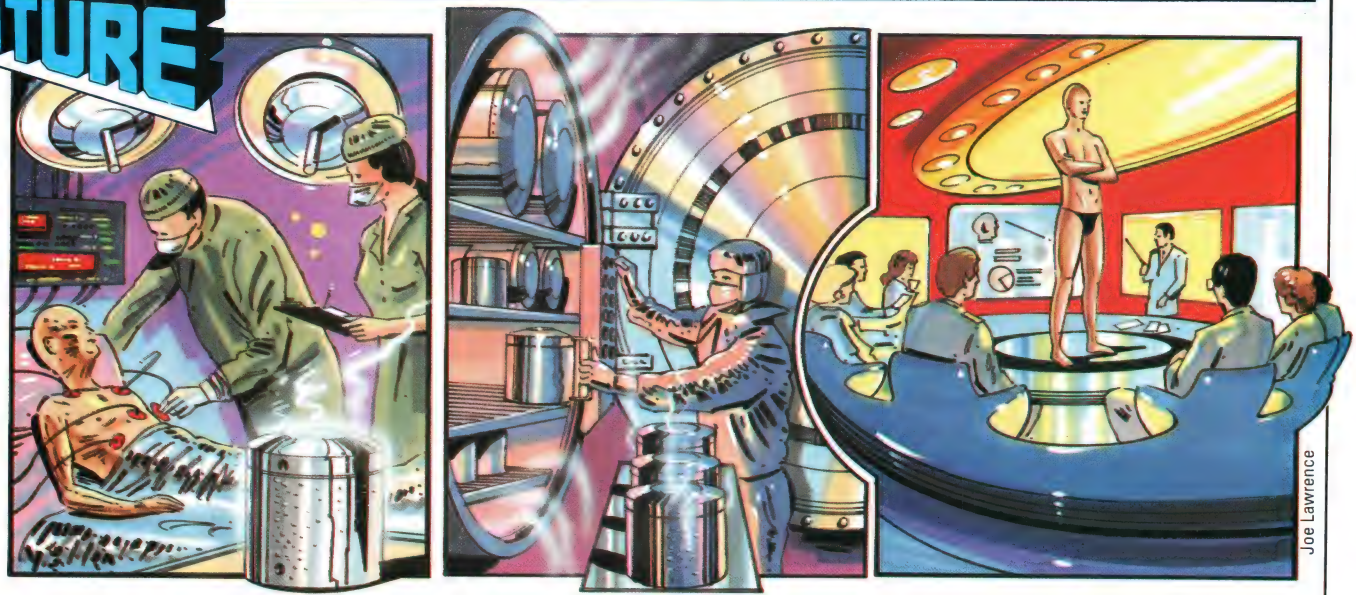
Similarly, the decline in mental powers among many old people is often made much worse by lack of stimulation. In many cases this can follow from loneliness, poverty and not having enough to do. Many people who 'age successfully' make conscious efforts to maintain mental alertness by continuing to learn and continuing to meet and talk to other people. Furthermore, older people who live independently in the community are more likely to be content and mentally alert than those living in old people's homes.

CNRI/Science Photo Library

***A knee joint** severely affected by osteoarthritis. The result of extreme wear and tear, it can cause great pain and hinder mobility.*

INTO THE FUTURE

FROZEN IN TIME



Joe Lawrence

▲ *Organizations in several countries now offer the chance of life after death. For a fee they will freeze the body – or just the head – of someone who has just died.*

▲ *The corpse will be kept in a vacuum flask for years – perhaps centuries – until medical science has learned how to restore the person to life.*

▲ *Eventually the remains will be brought back to life. If the head alone has been preserved, the rest of the body will have to be completely regenerated.*

George Bernard/Oxford Scientific Films

Insect lifespans vary greatly, from the few hours of a mayfly to the 20 or 30 years of the death-watch beetle.

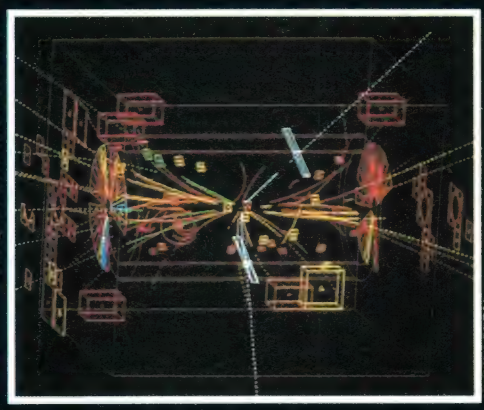
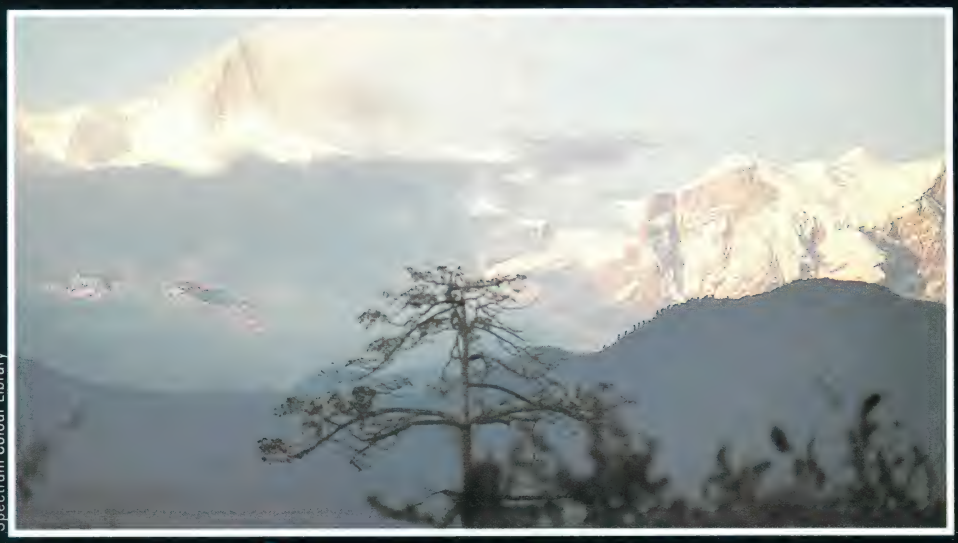


PHOTO CERN

Subatomic particles, revealed by smashing bits of atoms into each other, exist for less than a ten millionth of a second.

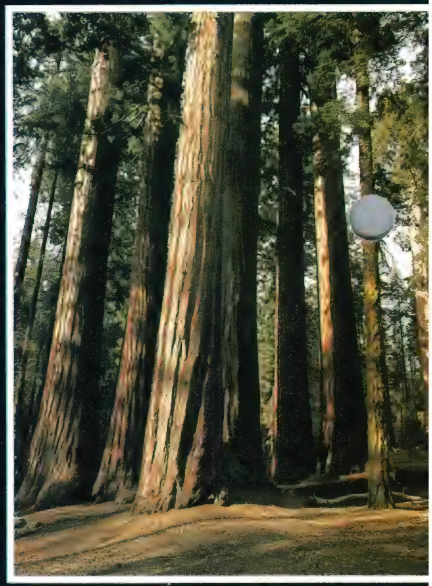
David Parker/SPL

A lightning bolt is simply a large spark discharging between a positive and negative charge.



Spectrum Colour Library

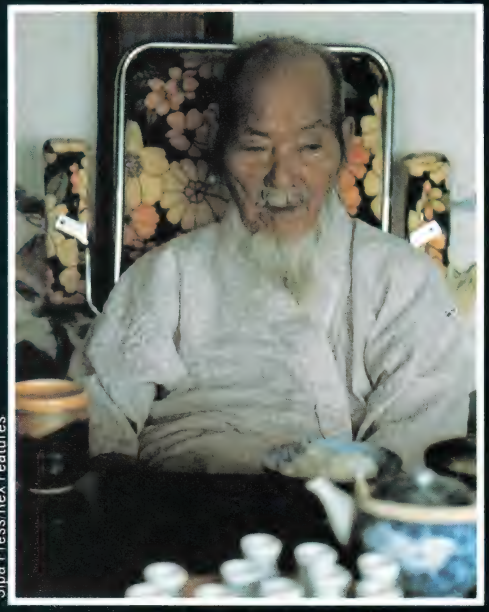
At 40 million years old, the Annapurna mountains in Nepal are youngsters compared with the Earth itself.



The oldest living things on planet Earth include the giant sequoia trees of California, with ages estimated to be between 3,500 and 4,000 years old.

Spectrum Colour Library

The Rosette Nebula is a vast cloud of rotating gas several million years old, but its stars are less than 500,000 years old.

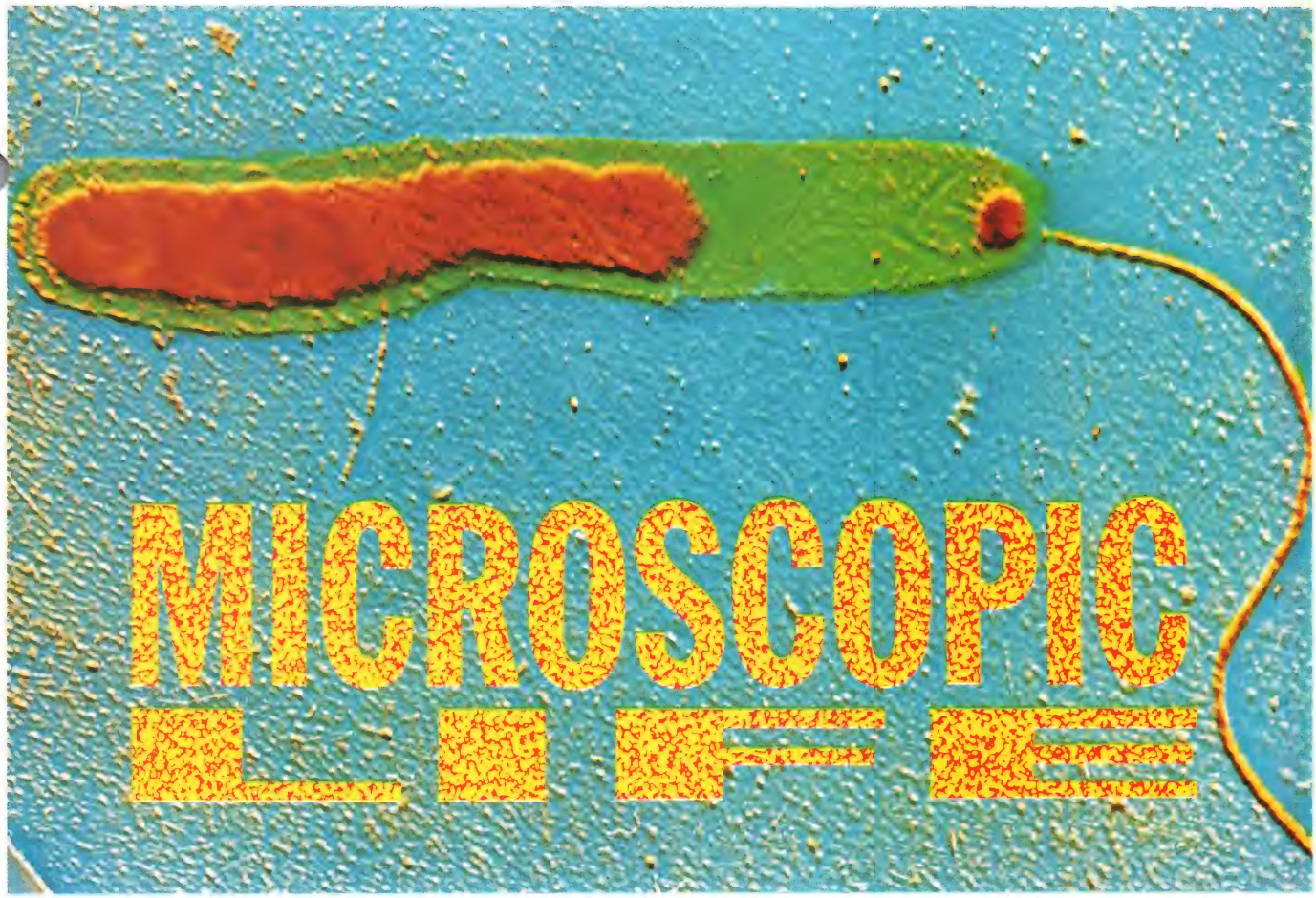


Sipa Press/Rex Features

The oldest recorded human life is that of Japan's Shigechiyo Izumi who reached an age of 120 years 237 days. He was born on 29 June 1865 and died, at home, on 21 February 1986.

Eric Grave/SPL

A true immortal is the trumpet-shaped freshwater ciliate, a simple, single-celled animal. Its bell-shaped mouth is covered with hair-like filaments which beat, drawing in food particles.



CNRI/SPL

MICROSCOPIC LIFE

KILLER BACTERIA

MICROSCOPIC FOOD

STERILIZATION

EVEN THE CLEANEST NATURAL source of water is home to a vast range of microscopic plants and animals. These organisms are infinitely smaller and simpler than any aquatic predator but, in millions, they can be as deadly as a shark.

Water is a particularly efficient medium for spreading organisms like those that cause gastro-intestinal infections, such as cholera and typhoid. These diseases are caused by bacteria — tiny organisms that are visible only under the lens of an extremely powerful microscope. ,

Bacteria are single-celled organisms. Most are between 0.0005 and 0.002 mm long. They reproduce by binary fission — they divide in two, doubling rapidly. Given food and warmth, some can reproduce once every 20 minutes. When bacteria invade the body, they do so in millions — not singly — and the doubling process soon leads to astonishingly large numbers.

***The bacterium** that causes cholera swims through water by wiggling its single 'flagellum' or thin, whip-like tail. In drinking water, it can kill.*

Cholera is carried by a torpedo-shaped bacteria called *Vibrio cholerea*, and drinking water contaminated with human faeces is the main cause of infection. The cholera bacteria prevents the body absorbing salt. This causes diarrhoea, followed by vomiting, dehydration and even death.

Typhoid epidemic

Typhoid fever is caused by *Bacillus typhosus* — a rod-shaped bacteria with hair-like appendages. After infection, the bacteria incubates for up to 14 days. Symptoms include diarrhoea, nose bleeding and rose-coloured spots. After an attack, bacteria remaining in the intestine makes the victim a carrier of the disease.

Most water-borne diseases are as old as human civilization. But in 1976, a new disease struck in Phi-

Mark Edwards/Still Pictures

***Cholera's effects** are swift and deadly. In areas of the world where sanitation is poor, bacteria in the faeces of victims gets into the water system, infecting more people and causing an epidemic.*

ladelphia. Delegates at a convention of the American Legion were struck down with pneumonia-like symptoms.

Altogether, 34 people died in the outbreak. After an exhaustive search for clues, the bacteria that cause the disease were isolated and named *Legionella pneumophilia*. The bacteria breed in air conditioning cooling tanks, and the disease is now known as legionnaire's disease.

Kim Westerskov/Oxford Scientific Films

***Many deaths** have been caused by legionnaires' disease. Since it was first discovered in 1976, there have been several outbreaks around the world. In each case* Legionella pneumophilia *have been discovered in the reservoirs of air conditioning systems or water storage tanks. Men are less resistant than women. Outbreaks in hospitals are especially dangerous.*

Warren Williams/Planet Earth Pictures

***Raw sewage** pumped straight into the sea can be dangerous as well as unsightly. Cholera bacteria in human faeces (inset) can be filtered out by shellfish. Eaten uncooked, they re-infect humans.*

Not all bacteria are harmful, however. Certain bacteria live in the human intestine and produce vitamin B12, important for general good health, and vitamin K, which helps blood to clot. Others are used to convert milk into cheese and yoghurt. Today, genetic engineers can grow specific types of bacteria to break down virtually any organic substance, including petroleum.

There are other small organisms called protozoans. Like bacteria, dangerous protozoans lurk in fresh water and moist soils, and they can be very harmful.

Entamoeba histolytica causes amoebic dysentry in humans. It is usually taken into the body in contaminated drinking water and causes serious ulcers in the intestine. But if it penetrates the blood vessels and gets into the liver, the results can be fatal.

Barry Dowsett/SPL

Not all water-borne organisms pose a threat to human life. The amoeba and paramecium are two of the many harmless microorganisms living in ponds, streams and generally moist environments. They, like many bacteria, feed on dead and decaying matter.

Ocean food

Plankton — a mixture of many tiny animals and plants — is found in the upper 100 metres of the oceans. The plants (called phytoplankton) convert sunlight and dissolved nutrients into food. Some of the animals (zooplankton) feed on them; others feed on the plant-eaters. Larger animals, such as fish, feed on the zooplankton, which is also a potential source of food for humans, too.

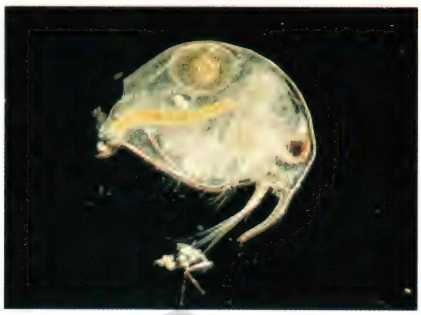
Water fleas, both freshwater and marine species, contain all the amino acids essential in the human diet. Up to 60 per cent of the dry weight of small crustaceans is protein. Tests are under way to farm phytoplankton and zooplankton to provide food.

Oxygen free

Not all bacteria require oxygen. One type is actually poisoned by it. These anaerobic ('without air') bacteria release oxygen-free compounds, such as methane.

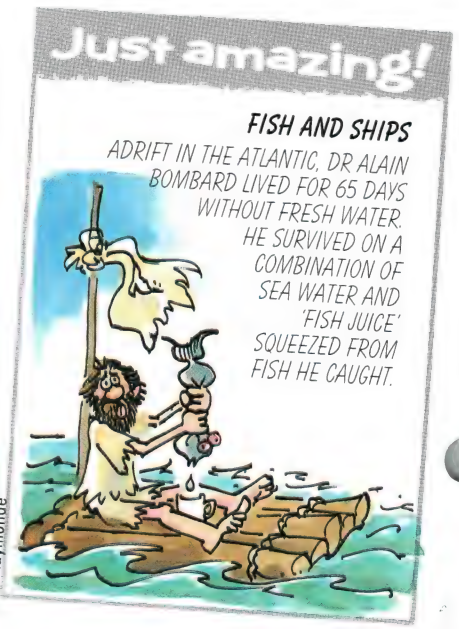
The sulphur bacteria also live in conditions where oxygen is scarce or absent. Some species have been found in hot springs at temperatures approaching the boiling point of water, where they feed on sulphur compounds.

Most harmful bacteria can be killed by boiling, however. In fact, heating water to just 63–66°C for 30 minutes, or 72°C for 15 minutes is enough. Where there is a real risk of contamination, however, water should be boiled. Another way to sterilize water is to add iodine or chlorine tablets.



Geoscience Features Picture Library

***Water fleas** eat microscopic organisms. They also contain all the protein humans need – but you'd need over a million to make up a fishfinger.*



Paul Raymonde

SELF DEFENCE

- FIGHT OR FLIGHT
- MARTIAL ARTS
- DEFENCE CLASSES

WHEN DANGER THREATENS, your body starts to change. Your heart beat rises. Adrenalin, the so-called 'fight or flight' hormone, is pumped into your system. More oxygen goes to your brain. You are preparing to run or fight.

The increased heartbeat makes your face redden, which is designed to frighten off a potential attacker. In this excited state, you are better equipped to deal with danger than in a normal situation.

Personal security depends on the ability to run or fight when under attack. Many people feel that relying on their natural reflexes is not enough. They feel better prepared and more confident if they are trained in some form of self-defence, notably one of the martial arts.

Martial arts harness these natural reactions to create a fighting capability of enormous power. But just as importantly, they instil a sense of discipline and restraint; true exponents only fight when they have to.

All the martial arts originate in the Far East. One of the most popular forms is karate, which has been described as the 'ultimate art of unarmed combat'. Built around the basic techniques of punching, striking, kicking and blocking, karate aims to focus all the body's power in a particular move. You may have seen karate practitioners chop through bricks with their hands, or

These hands can kill! *Karate is one of the deadliest forms of unarmed combat, and can be lethal if not practised properly. But exponents use their skills in competition only.*

ZEFA

Giving bricks the elbow *is simple for a karate expert. They can smash solid objects by concentrating all the body's energy into one small area.*

break planks with a kick. These are really only party tricks that show how power and control can be developed.

Holding back

'Free-sparring' competitions demonstrate how to land a blow on your opponent. As such blows can kill, the real skill is in stopping short of actually applying the blow.

Kung fu is a variant of the Chinese Chung-Kuo Chu'an (fist or hand) style of fighting. Like karate, it uses both the hands and the feet to attack an opponent. Kung fu has two sides to it; the 'external' and the 'internal'. The 'external' style is classified as true martial arts. These are purely designed to help someone defend themselves against an attacker, and might involve spitting, poking, butting, stamping – activities generally frowned upon by martial arts' practitioners.

As cases of violent crime rise, self-defence classes are becoming popular. Most local authorities offer classes to women, who may be afraid to travel on their own after dark. They are designed to boost the woman's confidence as well as give her the knowledge to protect herself from potential attackers.

It must be stressed that martial arts can be extremely dangerous if practised by the untrained. If you want to practise any of the skills, join a class or club with approved instructors.

all aggression while the 'internal' style gives the appearance of weakness. The idea is to lure the opponent into striking, then turn the power of the attack back on to him. As in karate, the true kung-fu practitioner is happiest when he knows he has the skills but does not use them, except as exercise for the mind and body.

Forbidden moves

Judo or ju-jitsu comprises four basic skills: how to fall when thrown, how to throw an opponent, how to apply arm locks and strangle holds and how to pin an opponent to the ground. A fifth skill, which involved striking at an opponent's weak spots such as the eyes and groin, used to be taught but is no longer in use.

Aikido, which translates as 'martial spiritual harmony', was developed in Japan during the 19th century in an attempt to create the ultimate fusion between the physical body and the spiritual mind. Like judo, it uses the force of the attack for its own power – the opponent's strength is used to defeat him.

There are other forms of martial arts that are not designed to help in an everyday situation, such as kendo, which uses armour and weapons. Likewise, there are other forms of self-defence that are not

JUDO GRADES

Caroline Brodie

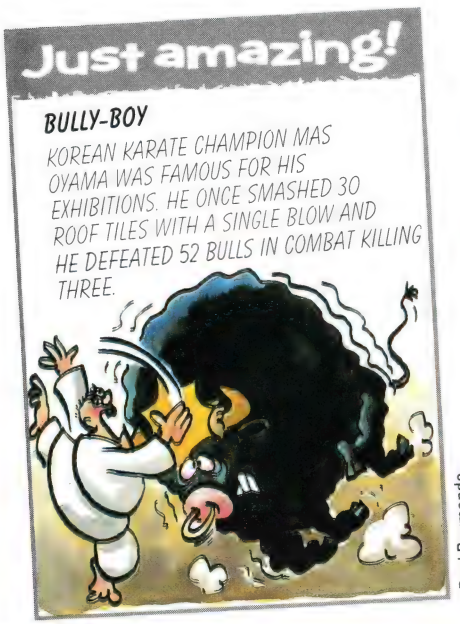
In judo, the skill of a practitioner is signified by belts divided into kyu (pupil) and dan (degree) sections. A beginner (6th kyu) wears a white belt with the fighting costume, and progresses by examination.

Above the 5th Dan, the awards are made on the basis of a 'master's' contribution to the development of the art rather than merely fighting skill.

Only one man has ever reached 12th Dan – Dr Kano, judo's founder.

Richard Francis/Action Plus

Taekwondo *can be practised by men and women equally. It is an excellent way of combining sport, fitness and a form of self-defence.*



Paul Raymonde

TUNING IN - HOW WE HEAR

David Redfern

- NERVE IMPULSES
- EAR DISEASES
- ECHO LOCATION

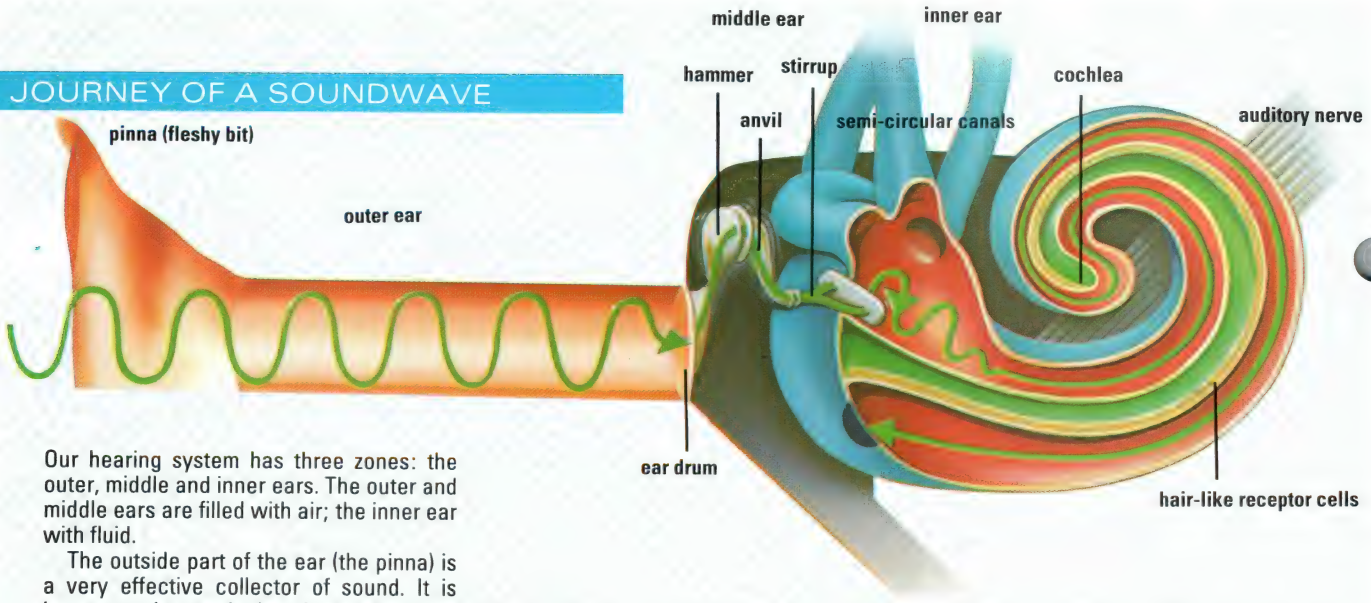
HEARING SEEMS LIKE THE easiest, most natural thing in the world – in fact it is a fantastically complex business. Your ears can both detect the faint buzzing of a bee and analyse the roar of a jet engine a million million million times louder.

Sound travels to us through the air as *compression waves*. The ear picks up these waves and sends detailed information about them to the brain. It is then that we are aware of the sound.

The nerve connections from the

ZEFA

JOURNEY OF A SOUNDWAVE



Advertising Arts

Our hearing system has three zones: the outer, middle and inner ears. The outer and middle ears are filled with air; the inner ear with fluid.

The outside part of the ear (the pinna) is a very effective collector of sound. It is important in particular for helping us understand which direction sound is coming from. The pinna channels the sound down the auditory canal into your ear – towards the middle ear – where the sound waves strike the ear-drum. This is a membrane which forms a barrier between the outer and middle ears.

Like the skin of a drum, the membrane vibrates when sound waves hit it. These vibrations are transmitted across the air-filled middle ear to the inner ear by the three smallest bones in the body – the hammer, anvil and stirrup. These act together as a mini amplifier.

The inner ear is made up of a series of canals which control our balance. They are known as the semi-circular canals.

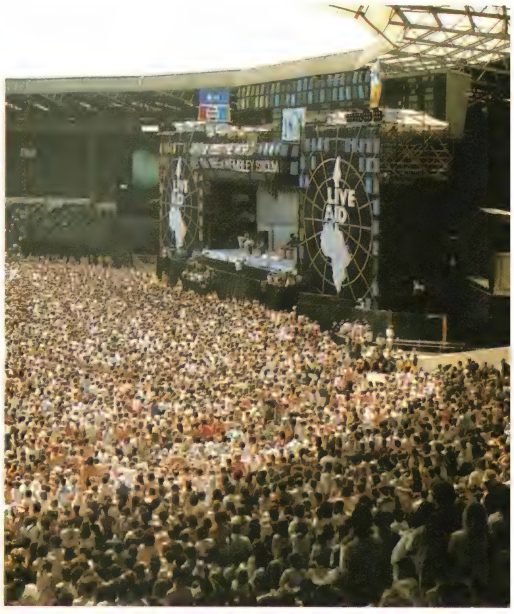
Another three canals, coiled in the shape of a snail's shell, are called the cochlea.

The stirrup is connected to the inner ear at a thin membrane called the oval window. Movement of this causes waves in the fluid in the canals. These waves are detected by over 20,000 tiny hairs on the inside of the cochlea. The movement of these hairs stimulates nerve cells at their base.

Signals from the nerve cells go down the auditory nerve to the brain, where they are interpreted – and we hear the sound.

SH & DH Cavanaugh/Robert Harding Picture Library

A personal stereo *puts you in a world of your own – but high volume at such close quarters can damage your hearing by killing the tiny hairs in your inner ear that detect sound.*



David Redfern

Massive volumes *of sound are required to fill Wembley Stadium. Those at the front can literally feel the compression waves from the heavy bass notes being absorbed deep in their chests.*

ears to the brain are crossed. Sounds in the right ear are mainly handled by the left side of the brain, while sounds in the left ear are handled by the right side.

The two sides of the brain seem to specialize in different types of sound. When different words are put through the two earpieces of a pair of headphones at the same time, words going in the right ear are more easily unscrambled. The opposite is true of music – music going into the left ear is heard more distinctly. So scientists believe that the left side of the brain is responsible for analysing language, and the right side music.

Attention

Concentration is another factor in hearing. You can hear the sound of a quiet conversation that you are interested in over loud background noises – this is called the 'cocktail party effect'. However, if certain words – your name in particular – occur in the rejected background sound, your attention immediately switches to it.

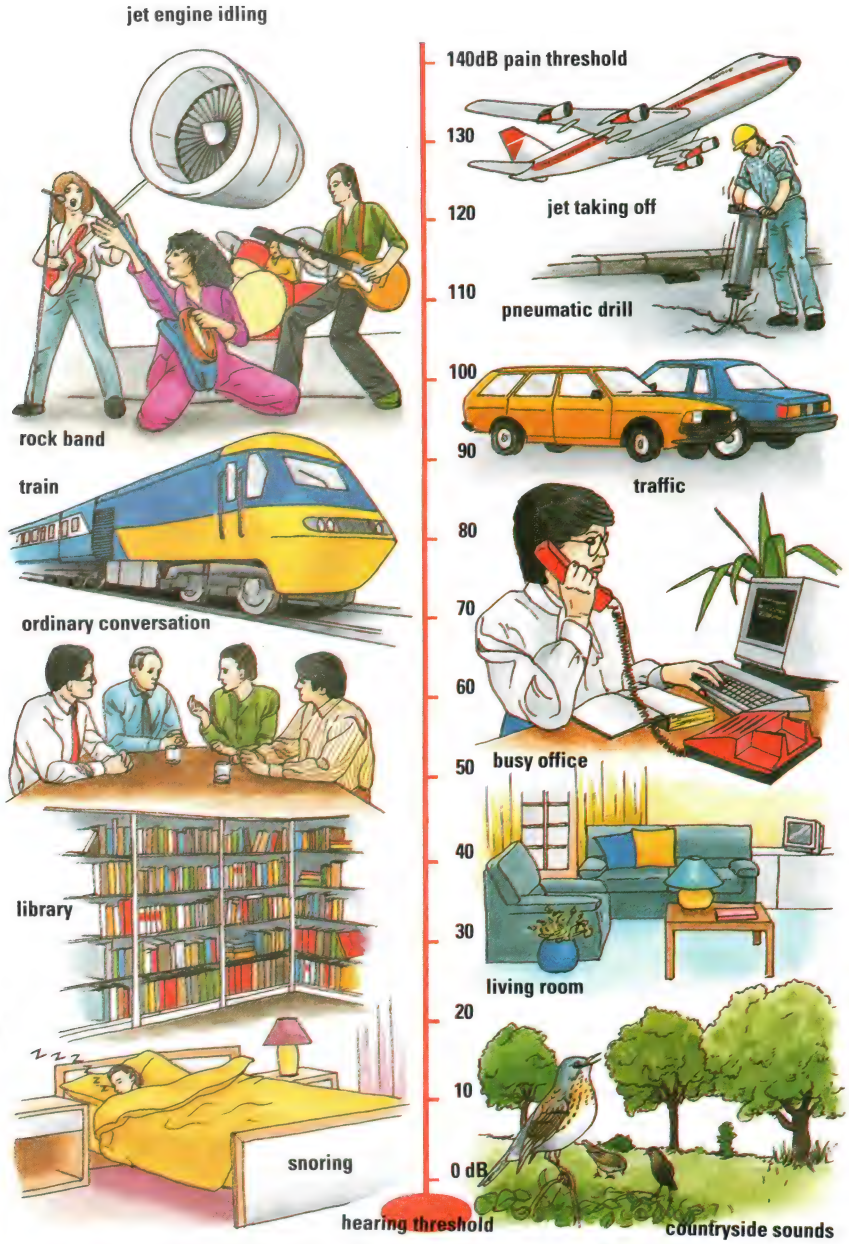
In the 'civilized' world it is accepted that hearing deteriorates as you grow older. The small bones of the middle ear become progressively less mobile and the hairs of the inner ear die off. But tests of certain African tribes show no hearing loss among the elders. A study of 500 Mabaan tribesmen showed that nearly all of them, regardless of age, could hear a whisper over the length of a football pitch. Perhaps our noisy Western world – full of

Just amazing!

VROOM, VROOM

FISH MAKE NOISES TO ATTRACT A MATE. MINNOWS PURR, COD GRUNT, WHILE THE LOVE SONG OF THE HADDOCK SOUNDS LIKE A MOTORBIKE.

Paul Raymonde



Caroline Brodie

The decibel (dB) scale *is not a straight forward measure of sound intensity. Doubling sound intensity does not double the dB. It adds just over 3 dB to the measurement.*

Gamma/Frank Spooner Pictures

In music, *blindness is no handicap, as singer and multi-instrumentalist Stevie Wonder proves. The blind have to 'see' with their ears, so their hearing becomes exceptionally acute.*

the sounds of cars, radios, aeroplanes and building sites – causes the progressive loss of hearing.

Insects can hear, too. Even the blowfly has receptors in the joints of its antenna that can detect sound. Nocturnal moths have membranes on either side of their bodies connected to receptor cells. Using these, they can detect the ultrasonic cries of hunting bats and turn themselves to make the smallest possible target. Male mosquitoes have their hearing finely tuned to sounds between 150 and 550 Hz, the wing tone of the female.

Fish do not need an outer and middle ear. Since fish tissues are about the same density as water they can detect the sound vibrations directly in the inner ear. Some fish have a gas-filled bladder connected by bones to the inner ear which acts as a kind of eardrum.

Most reptiles have their eardrums on the outside of their bodies, but birds, like humans, have their eardrums inside their heads connected to the surface by a canal.

Night sight

The barn owl uses its extraordinary hearing to capture mice even in total darkness. Its ears are placed at slightly different angles – its right ear is turned slightly upwards, the left slightly down. By comparing the sounds in its two ears, it can fix its prey's position precisely. It can even determine the direction in which a mouse is moving, in order to fasten its talons along the line of the mouse's body.

Stephen Dalton/NHPA

The highly developed hearing *of the mouse-eared bat means that it can catch its prey even in pitch blackness. Echoes of the ultrasonic squeaks it emits are detected by its direction-sensitive ears, so it can locate even the smallest flying insect.*

Shrews, oilbirds and the Himalayan cave swiftlet 'see' in the dark using echo location. They emit high-pitch sounds and detect objects from their echoes. Dolphins use a more advanced form of echo location, but it is bats that have perfected it.

Flying prey

Bats emit pulses of ultrasonic sound – outside the range of human hearing. That way they are not confused by the low-frequency sounds made by the wind and other natural phenomena. Again, the echoes tell them where things are.

Insect-eating bats have large external ears which are particularly sensitive. It is able to capture very small flying insects at the rate of two per second.

Robert Harding Picture Library

Simple resonating pipes *are blown by Brazilian Indian during the coming-of-age rites of Xingu Kuarup. The pitch of the note depends on the length of the pipe. The players here can produce two notes each.*

Jesco von Puttkamer/Hutchison Library

The nose flute *is played by Amazonian Indians. One nostril is closed with the thumb – the flute is blown with the other.*

Tony Stone Photo Library, London

Tony Stone Photo Library, London

Musical monks *in the Thikse Monastery at Ladakh, Tibet praise God by blowing on their sonorous Tibetan horns and banging large drums.*

A kongon *or mouthbow being played at Tapari in the Cameroons. The mouth is used as the sound box to amplify the note produced by the string.*

The din's the thing *at the Junkanoo festival on New Providence Island in the Bahamas. Providing it in abundance are drums, whistles, home-made horns, bells and rattles.*

An eccentric Englishman *strikes a low note with a length of piping amplified by an ordinary lavatory bowl – showing that almost anything will make a noise if blown, banged or plucked.*

JG Fuller/Hutchison Library

The gangsa or metallophone *is the principal instrument of a gamelan (percussion) orchestra from Bali. Similar in principle to the wooden xylophone, its metal strips are struck by a metal hammer.*

V & A Wilkinson/Hutchison Library

P Moszynski/Hutchison Library

Hutchison Library

The harp *is usually associated with Wales or Ireland. This South American version is being played in the Andes by a Quechua Indian, a descendant of the Incas.*

Driscoll Strawberry Associates

Crown copyright/Brogdale EHS

The Bug-Vac *was invented in California to combat the lygus bug, which lives on the top leaves of the strawberry plant. A huge vacuum cleaner on wheels, the Vac sucks up the bugs.*

PEST CONTROL

CHEMICAL POISONS

FARMERS ARE PLAGUED with pests that attack their crops and livestock. The pressure to get crop yields as high as possible and to rear large, healthy livestock has never been so great.

THE BUG-VAC

It is estimated that, even today, 30 per cent of possible world food production is lost to diseases, pests and weeds before harvesting and another 15 per cent is lost between being harvested and reaching the consumer.

IMMUNIZATION

Pesticides are chemical mixes put together by scientists that kill pests, be they insect, worm, weed or fungus. They are usually sprayed on to crops; animals can be sprayed or bathed in water in which the pesticide has been dissolved. Insecticides have a crucial role in the fight against insect-borne diseases, such as malaria, which affect man as well as other animals. Without pesticides cereal yields would drop by up to a quarter in the first year.

WAR AGAINST PESTS

Name	Acts against
Pesticide	Any 'pest' – anything that causes disease or poor growth in humans, pets, or farm animals and crops
Insecticide	Insects such as beetles, caterpillars, grubs, locusts, fleas and flies
Acaricide	Mites and ticks, often infesting cattle and sheep
Nematocide	Roundworms; thread worms; nematodes
Rodenticide	Rodents, such as mice, voles and rats
Molluscicide	Molluscs, such as slugs and snails
Herbicide	Weeds – plants growing where they are not wanted
Fungicide	Fungi, such as plant mildews and rusts; also moulds

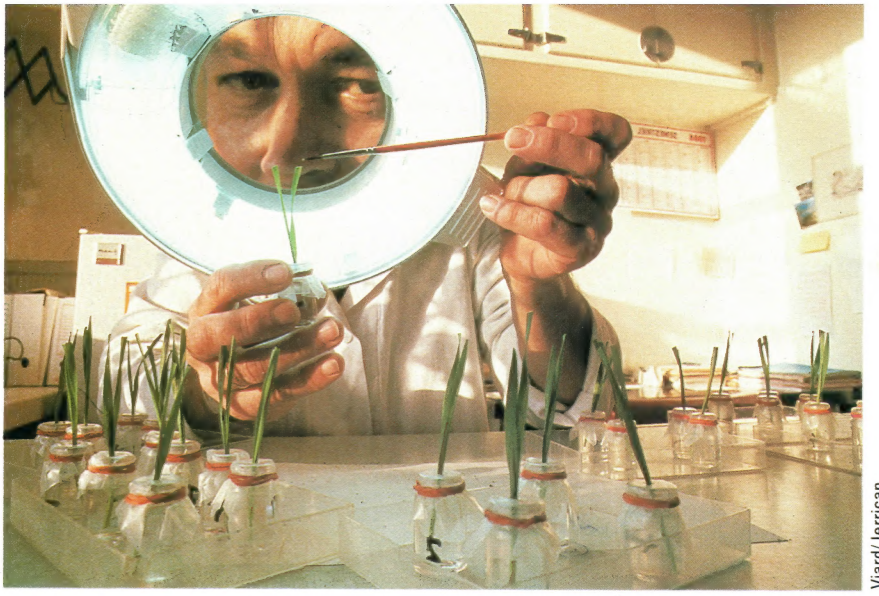
New pesticides

Enormous sums of money are spent on developing and testing new pesticides. As many as 10,000 new chemical compounds have to be tested to produce just one new pesticide. This process takes seven years or longer and may have cost up to £30,000,000 by the time the new pesticide is in the farmer's

MAN-MADE PEST

In an attempt to fight the beetles that were devastating the sugar-cane crop in Queensland, Australia, over 30,000 cane toads were imported from Hawaii, in the hope they would eat the insects. Unfortunately, the sugar-cane fields were too hot and dry for the toads – they spread into the surrounding bush and ate the native insects instead by the tonne. Cane toads are themselves poisonous if eaten and have caused the death of many animals (including dogs) that tried them for supper. The toads have now spread across much of eastern Australia.

Z Leszczynski/Oxford Scientific Films



Viard/Jerrican

In an experiment, *a scientist looks through a magnifying glass lit by electric light so that he can see the wheat seedlings on which he is painting a new pesticide.*

sprayer. Up to half this sum is spent on testing for poisonous effects on other forms of life and on how the chemical will behave when it gets into the environment – the soil, water and air.

But the big pesticide companies cannot measure and check every aspect of the long term effects of their products. When chemical pesticides are sprayed on the land there may be unwanted, dangerous side-effects. Pesticides contaminate the soil. Rain washes the soil and any pesticide chemicals it contains into streams, which run into rivers and lakes eventually contaminating the sea.

The food chain

Plants absorb some chemical pesticides either from direct contact or together with nutrients from the soil or water. Animals eat affected plants and may be, in turn, eaten themselves by bigger animals – such as ourselves. Thus the whole 'food chain' is polluted. Residues of DDT (an insecticide now widely banned) have even been found in Antarctic seals and penguins.

Chemicals that make up pesticides do not easily break down into harmless substances – the amount in a plant or animal slowly builds up as more and more of the chemical is absorbed. These chemicals are poisonous, and can even kill.

The USA alone manufactures $800,000,000 worth of pesticides each year and sells 40 per cent abroad. The use of DDT was banned in the USA in 1972 – yet American companies still make 18,000,000 kg of this chemical each year for export, mainly to poor nations.

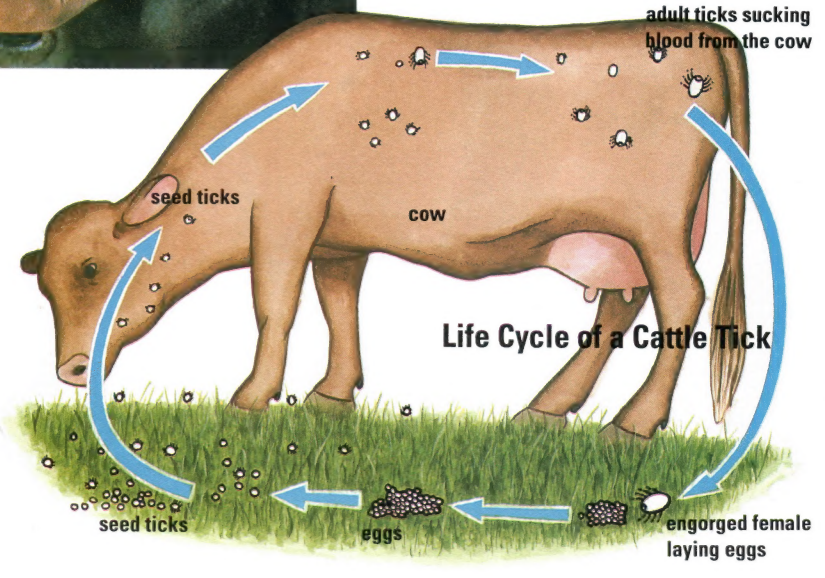
Often such pesticides are used without proper precautions by farm workers with outdated equipment who cannot understand the instructions, which are usually printed in English. At the same time, some farmers deliberately ignore the instructions and warnings printed by the manufacturers on the packaging.

Pesticides are, in general, used more carefully today than in the past because of our increased awareness of their side-effects. Some particularly poisonous pesticides have been banned – but the pests they attacked have still to be dealt with.

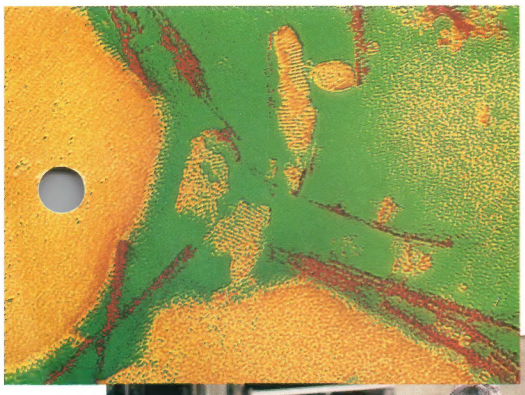
There has been a population explosion among the locusts in North Africa due to higher-than-average rainfall in the Western Sahara. Some experts in the region are calling for the return of dieldrin, a banned pesticide, to control the

Biotechnology Australia pty Ltd

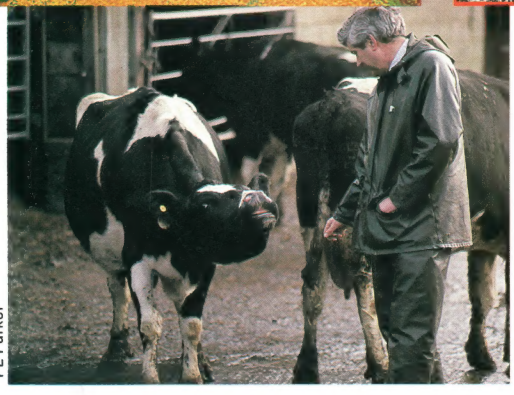
The eggs of a cattle tick *hatch into 'seed ticks', which swarm up grass blades and attach themselves to a cow – a favourite place is the inside of the ear. Once adult, the size of a matchhead, a female feeds for about a week. Engorged, she drops off the cow, lays up to 3,000 eggs and dies.*



John Houghton



EM Unit, CVL, Weybridge/SPL



PE Parker

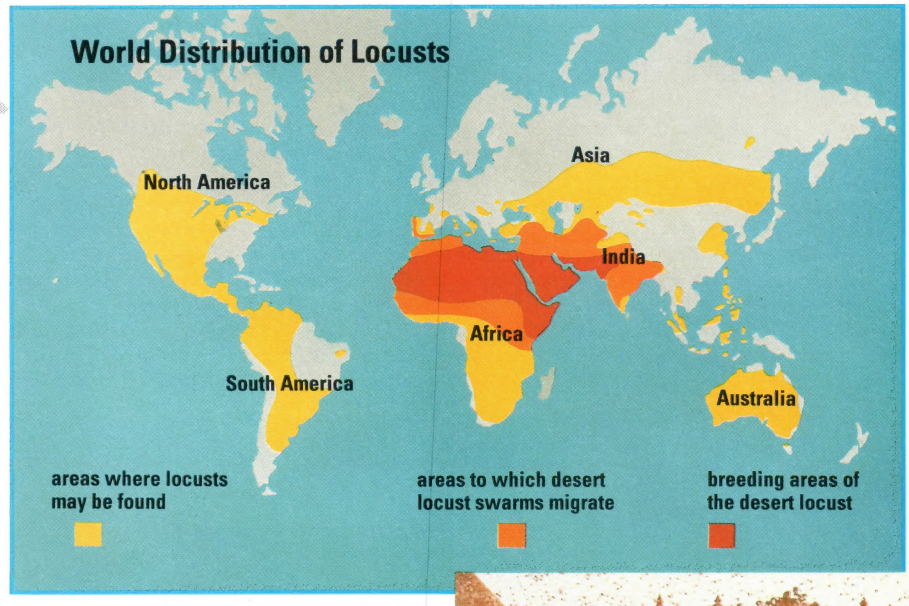
A new disease, *Bovine Spongiform Encephalopathy, has attacked 5000 cattle in Great Britain since the first case in 1986. The virus, which affects the brain, makes the cow go mad and destroys its muscular co-ordination (left). The disease was transmitted to cows from sheep; its name comes from the spongy nature of infected brain tissue (top left). All infected cows are slaughtered and burned (top).*

A locust swarm *will eat everything that is green, stripping the countryside bare (inset lower right). The biggest swarm of desert locusts on record covered an area of 5,000 square km and contained about 250 billion locusts.*

swarms and stop them spreading.

Immature locusts, called hoppers, do not have wings so they cannot move far. If a strip of land is sprayed with dieldrin, it will form a barrier that the immature locusts cannot cross, because the dieldrin will kill them. Fenitrothion, another pesticide, has been used but it quickly breaks down in the soil (thus doing less long-term damage) and so makes a less effective barrier. The swarms that have escaped the fenitrothion will produce huge future generations of locusts.

Sometimes machines can do the work of chemicals. In California, strawberry farmers now use great vacuum-cleaners to suck pest bugs off their crops. Strawberry pests include the lygus bug in the upper leaves, the western flower thrip in the lower leaves and the two-spotted spider mite on the underside of leaves.



Jeremy Banks

Gamma/Frank Spooner Pictures

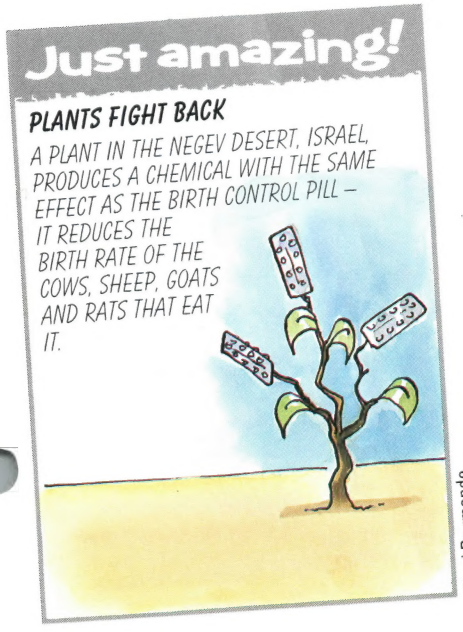
Hoovering crops

This last pest is so resistant to pesticides that the huge amounts needed to kill it would wipe out all the 'good' creatures that prey on the pests and keep the numbers under some sort of control. Enter the 'Bug-Vac', a four-part hoover mounted on a tractor that sucks over four strawberry rows at once. The lygus bugs are the main ones to be sucked up and 'blow-killed' as they pass through a fan at a speed of 30 miles an hour.

David Jackson

It might seem more sensible to exploit 'natural' poisons, instead of using 'unnatural' man-made ones. Spiders prey on insects, disabling and killing them with their poison fangs. Studies of the Japanese joro spider and European agriope have revealed the chemical structure of their poisons, which act as nerve paralysers. If the chemical could be slightly modified, it might be suitable as a short-acting insecticide that breaks down naturally.

However, it is also possible that if this insecticide were to be used on a huge commercial scale, some insects could develop an immunity



Paul Raymonde

to it and, therefore, to the poison of the spiders themselves. Since spiders kill and eat many more insects than the farmer could spray, this is obviously undesirable.

Instead of using an animal's poison, how about using an animal itself to control pests? 'Biological control' has been tried many times around the world – with mixed success.

A purple-flowering weed called Paterson's curse has spread over large areas of Australia. The weed reduces the quality of the soil and it also poisons farm animals. A type of moth was imported from France and released in south-eastern Australia in the hope its caterpillars would eat their way through the weeds' leaves and kill the plants. Whether this will be successful, and without side-effects, will not be known for a number of years.

Tony Stone Photo Library, London

Gamma/Frank Spooner Pictures

***Pesticides** can be used in a number of forms including granules, dusts and fumigants, but the majority are diluted in water and applied as sprays. Aerial spraying (above) is not very efficient – only 30 per cent of the spray lands on target.*

Instead of attacking the pest, another approach is to make the farm animal or plant resistant to it. In 1988 a vaccine against the cattle tick, which causes millions of dollars worth of damage among herds in Australia and South America, was produced in Australia.

The tick, a distant relative of the spider, fastens its sharp mouthparts on to an animal and can suck in 8000 times its own body weight in blood from the host. Milk production is affected, the cow's hide is damaged and diseases are spread from animal to animal.

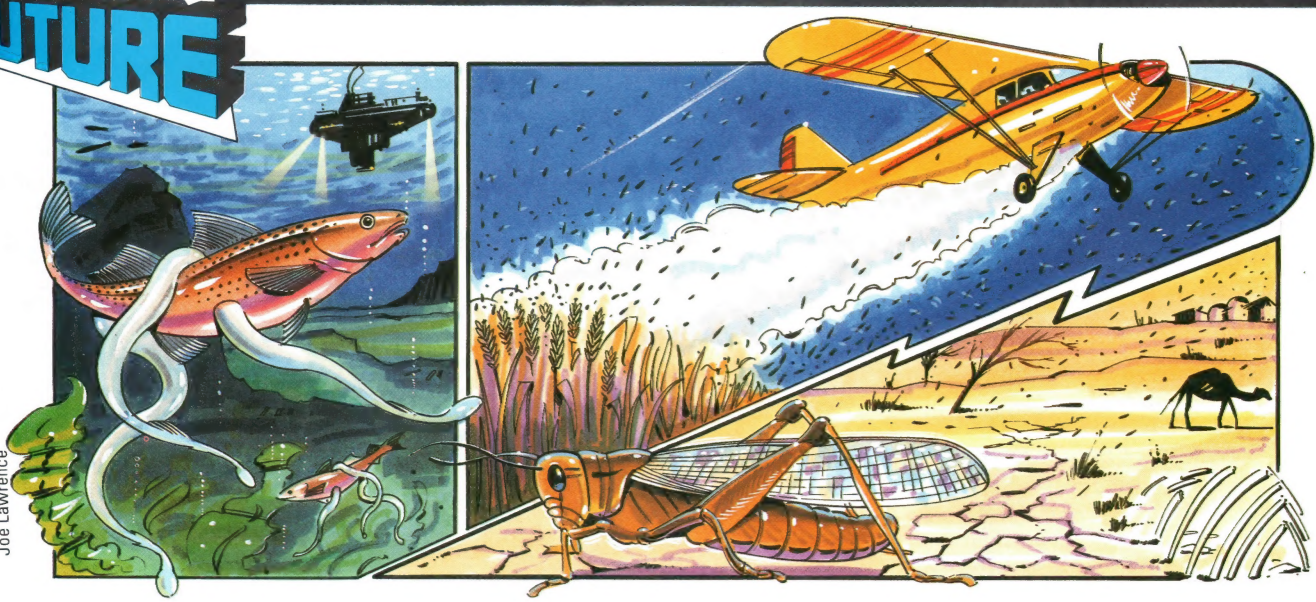
Jabs for cattle

In a series of experiments (each involving picking out up to 60,000 ticks from infested cattle with tweezers) scientists identified the substance that made some cattle naturally resistant to the tick. This was used as the basis of a vaccine, with which a cow is innoculated.

When a tick sucks blood from a vaccinated or naturally resistant cow, antibodies in the animal's blood destroy the tick's gut. The damaged tick drops off its host and dies. Once the vaccine gets into full production cattle ranchers should be able to use less anti-tick pesticide spray.

INTO THE FUTURE

SUPER-PLAGUES



Joe Lawrence

▲ *As fish we eat become sick in polluted seas there could be a plague of hagfish – a predator that preys on weak, diseased fish – creating a desert in the oceans.*

▲ *On land, pesticides will have to be used in ever greater strengths and ever greater quantities in order to deal with pests that mutate to obtain immunity.*

▲ *Eventually, the lack of a safe, effective weapon could mean a devastating plague of locusts, laying waste to whole areas of previously fertile land.*